ASSESSMENT OF
EXISTING FLOOD PROTECTION
IN UPSTREAM WATERSHEDS

THE RIVER'S REACH

CONNECTICUT RIVER BASIN
SUPPLEMENTAL STUDY

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

MARCH 1974

CONNECTICUT RIVER BASIN SUPPLEMENTAL STUDY

NEW HAMPSHIRE, VERMONT, MASSACHUSETTS AND CONNECTICUT

THE RIVER'S REACH

An Assessment of

Existing Flood Protection

in Upstream Watersheds

Phase 1 Report

(1.1 D, 1.3 D, 1.3 E, 1.4 D)

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Conservation Service

March 1974

SUMMARY

Introduction

In Phase 1 of the Connecticut River Basin Supplemental Study, the Soil Conservation Service (SCS) inventoried existing flood management systems in 17 upstream watersheds. The 1980 New England River Basins Commission plan identified these watersheds as areas of significant flood damages. The Soil Conservation Service, Bureau of Sport Fisheries and Wildlife, and the Citizens and Science Advisory Groups selected three watersheds with the most significant flood problems and critical environmental concerns. The SCS then studied in more detail these three watersheds to evaluate existing flood conditions and the effectiveness of the existing flood management system. To obtain public opinion on the flooding problems the SCS held a meeting in each of the three watersheds, and the Citizens Advisory Group held a series of public forums throughout the Connecticut River Basin. This summary discusses the above items. The full report contains more detailed information.

Inventory of Watersheds

The SCS inventoried 17 watersheds through a review of literature and past studies, map studies, field checks, and interviews. The inventory identified those existing flood management measures which provide some degree of protection--structural, nonstructural and natural storage. In the 17 watersheds there are 10 flood prevention dams, 9 local protection projects, 9 towns with flood plain zoning, 19 towns with subdivision regulations, and 4 communities with U. S. Department of Housing and Urban Development flood insurance. About 50 towns have significant flood hazard areas. All watersheds evidenced some level of floodproofing and warning and evacuation procedures. Natural storage exists in every watershed, although it is of negligible capacity in some.

Selection of Three Watersheds

Three watersheds were selected for further study. Two of these, Whetstone Brook and the Passumpsic River, were selected early in the study by the Soil Conservation Service and the Bureau of Sport Fisheries and Wildlife with the concurrence of the Citizens and Science Advisory Groups. The early selection permitted the two agencies to complete the study on schedule. The Citizens and Science Advisory Groups selected the Mill River as the third watershed. Ratings of flood risks and environmental considerations for each of the watersheds assisted them in their selection. The SCS prepared a report for each of the three watersheds which discusses flooding problems and existing flood management systems.

Passumpsic River Watershed

The Passumpsic River watershed is located in northern Vermont. The area studied includes the Moose River and the Passumpsic upstream of the Moose River and totals 374 square miles or 239,360 acres. Present land use in the watershed is estimated as follows: 74 percent forest, 20 percent agriculture, and 6 percent urban and miscellaneous.

Notable flood damages have occurred in the Passumpsic at least 17 times in the last 150 years. The greatest flood occurred in 1927.

There are over 7,000 acres of flood plain in the watershed. The majority of the land is in woodland and wetland use.

TABLE S-1

FLOOD PLAIN LAND USE
PASSUMPSIC RIVER WATERSHED

Land Use	Acres	Percentage
Agriculture	2,220	32
Woodland and Wetland	3,670	52
Urban	310	4
Miscellaneous	850	12
TOTAL	7,050	100

The watershed was analyzed and a synthetic range of floods was developed to represent floods which could be expected to occur in return periods of 5 to 100 years. These studies also reconstructed the historical floods of November 1927 and June-July 1973. These studies showed that the 1927 flood was slightly larger than the 100-year event. The 1973 flood was the largest since the 1927 flood.

Major flood damages to residential, industrial and commercial development result, primarily along the Passumpsic in Lyndon and St, Johnsbury. Agricultural damages occur along the major upstream tributaries and transportation damages are spread throughout the watershed.

TABLE S-2

FLOOD DAMAGE SUMMARY FOR THE PASSUMPSIC RIVER WATERSHED ABOVE THE SLEEPERS RIVER

Event	Damage(Dollars)
10-year flood	474,000
25-year flood	2,117,000
50-year flood	5,002,000
100-year flood	7,510,000
1927 flood	8,927,000
1973 flood	1,838,000

The average annual damages are $539,200.

Existing development in the flood plain remains unprotected from flooding. Some areas flood on an annual basis and a 10-year event causes widespread flooding and significant damage.

The Corps of Engineers developed a flood plain information report for St. Johnsbury. The SCS has developed a similar report for Lyndon. The reports delineate the major flood damage areas. Both towns have adopted flood plain zoning ordinances. St. Johnsbury's ordinance regulates development up to the 100-year flood level, encompassing about 1,000 acres. In Lyndon, zoning regulates an area approximated by the 20-year flood plain and involves about 800 acres. The effectiveness of zoning in both towns will depend on enforcement of the regulations because only 15 percent of the flood plain is developed.

Whetstone Brook Watershed

The Whetstone Brook watershed is located in Windham County in southeastern Vermont. The drainage area is 28 square miles, or 17,900 acres. Present land use in the watershed is estimated as follows: 78 percent forest, 6 percent cropland, 4 percent pasture, 5 percent urban, and 7 percent miscellaneous. The watershed is steep; the stream is very flashy and can reach peak flows in only a few hours.

Damaging floods have occurred in the watershed in 1869, 1927, 1936, 1938, 1955, 1969, and 1973.

The major flood plain area along Whetstone Brook, in the town of Brattleboro, is about 200 acres in size. Additional flood plains exist along tributary streams, especially Ames Hill Brook.

TABLE S-3

FLOOD PLAIN LAND USE
TOWN OF BRATTLEBORO

Land Use	Acres	Percentage
Urban	130	62
Agriculture	40	19
Miscellaneous	40	19
TOTAL	210	100

The largest flood of record is the 1938 hurricane. The 1973 flood was not severe in the watershed, but its effects varied markedly throughout the state. Flooding would have been severe if rainfall received 30 miles away had fallen over the watershed.

Flood damages in the watershed occur mostly to residential and commercial property. Residences consist of semipermanent mobile homes, multiunit housing developments for the elderly, apartment units, and single family homes. There are nearly 400 such units on the flood plain.

A major flood in the watershed would result in about 3.2 million dollars worth of damage.

TABLE S-4

FLOOD DAMAGE SUMMARY
WHETSTONE BROOK WATERSHED

Event	Damage(Dollars)
10-year flood	155,000
25-year flood	1,571,000
50-year flood	2,026,000
100-year flood	3,237,000
1973 flood	150,000
1938 flood	2,887,000

The average annual damage for the watershed is $226,800.

There are no structural measures to protect flood plain residents and development in the event of a large flood. Brattleboro has developed flood warning and evacuation procedures to alert residents in the flood plain. The system is effective, but the reliance on upstream residents for warnings, the lack of formal procedures and the "wait and see" attitude of residents tend to reduce its effectiveness.

The Corps of Engineers has prepared a flood plain information study for the town of Brattleboro. The town uses this report, along with local and state regulations, to control development in the flood plain. The town of Marlboro, on the headwaters of the Whetstone, has flood plain zoning.

Brattleboro has been accepted into the HUD national flood insurance program on an emergency basis.

Federal agencies, including the National Weather Service, the Soil Conservation Service, and the U. S. Army Corps of Engineers, have studied flood problems in the watershed. A plan for protection has not yet been finalized.

Mill River Watershed

The Mill River watershed is located in Hampshire and Franklin Counties in Massachusetts. The watershed encompasses about 59 square miles or 37,800 acres. Land use is estimated as follows: 74 percent forest, 9 percent cropland, 5 percent pasture, 7 percent urban, and 5 percent miscellaneous.

There are about 1,700 acres of flood plain along the Mill River in Northampton and Williamsburg. Of this, about 1,000 acres is a part of the flood plain common to the Connecticut and Manhan Rivers. Land use in the common flood plain is evenly divided between agriculture and wetland. Land use in the Mill River flood plain is estimated in the following table.

TABLE S-5

FLOOD PLAIN LAND USE 1/
MILL RIVER WATERSHED

Land Use	Acres	Percentage
Agriculture	170	24
Urban	140	20
Wetland and Woodland	310	44
Recreation Areas	80	12
TOTAL	700	100

1/ Excluding flood plain common with Connecticut River.

Major flooding occurred in the Mill River watershed in 1936, 1938, and 1955. The largest flood of record is the September 1938 hurricane. A flow of 7,330 cfs was measured at the Haydenville Dam on September 21. The 1955 flood varied markedly throughout the region and the Mill was not hit as hard as nearby areas. A flow of 6,300 cfs was measured at the gaging station in Northampton on August 19.

Under present conditions the 100-year flood would result in damages of about $1,135,000. Property susceptible to damage includes about 100 residences, 20 commercial concerns, a major industry and recreation areas. Damages for other events are given in the following table.

TABLE S-6

FLOOD DAMAGE SUMMARY
MILL RIVER WATERSHED

Event	Damages(Dollars)
10-year flood	0
25-year flood	255,000
50-year flood	735,000
100-year flood	1,135,000
1955 flood	132,000
1938 flood	860,000

The average annual damage for the watershed is $64,900.

As a result of the 1936 and 1938 floods, the Corps of Engineers developed a local protection project for the city of Northampton. The project protects the downtown area from a 100-year event on the Mill River through a dike and a diversion.

In the village of Florence, a major manufacturing company has installed floodproofing measures in its plant.

The city of Northampton is taking an active role in developing a flood management plan. It has organized a flood emergency board to carry out warning and evacuation procedures in the city. The city is a participant in the HUD flood insurance emergency program. A new zoning law is being drafted which, if approved, will control development in flood hazard areas.

The town of Williamsburg is also in the process of planning controlled use of flood hazard areas.

Local Interest Groups

The Soil Conservation Service held a public meeting in each of the three watersheds and the Citizens Advisory Group held public forums throughout the Connecticut River Basin. These meetings were helpful in explaining the current study and provided an opportunity to listen to the opinions and ideas of local citizens concerning flood problems.

At the SCS public meetings and the public forums, participants expressed ideas applicable to a flood management program in upstream watersheds. These dealt with endorsements for flood prevention, sedimentation control, flood plain land use regulations, relocation out of flood hazard areas, educational effort to inform people, consideration of the development rights of flood plain landowners, encouragement of wise land use in upstream areas as well as in flood plains, and others.

PREFACE

The Soil Conservation Service (SCS) and the Economic Research Service (ERS), agencies of the U. S. Department of Agriculture, are participating in the Connecticut River Basin Supplemental Study. The SCS is responsible for flood management studies in the upstream watersheds and the ERS for economic impact studies.

This report covers work assigned to the SCS in the New England River Basins Commission Plan of Study with the following objectives:

- 1.1 D Select floods to test alternative plans.
- 1.3 D Route floods through existing upstream systems.
- 1.3 D Assess damage reduction existing upstream system.
- 1.3 E Assess damage reduction, existing upstream management techniques.
- 1.4 D Identify major upstream damage centers.

The study responsibilities for ERS are not directly related to SCS studies and have been completed separately. The ERS will report on the results of their work in a separate report.

The SCS appreciates the effort and time put forth by members of the Study Management Team (SMT) and the Citizens and Science Advisory Groups (CAG and SAG) and others in reviewing the draft report. Modifications have been made in the final report where it was found appropriate to accommodate their comments.

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EXISTING FLOOD PROTECTION
IN UPSTREAM WATERSHEDS

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(1.1 D, 1.3 D, 1.3 E, 1.4 D)

prepared by the

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

for the

CONNECTICUT RIVER BASIN SUPPLEMENTAL STUDY
New Hampshire, Vermont, Massachusetts, Connecticut
March 1974

INTRODUCTION

The New England River Basins Commission 1980 Connecticut River Basin Plan has assigned the Soil Conservation Service the task of reevaluating flood damages and studying alternative measures for prevention of flood damages in the upstream watersheds of the Connecticut River Basin. The Soil Conservation Service has completed the initial phase of its task.

This interim report presents the findings of the study conducted by the Soil Conservation Service as its part of Phase 1 of the Connecticut River Basin Supplemental Study. The Soil Conservation Service "Plan of Work", dated September 1973, provides background and a schedule for completing the study. This Phase 1 report will be followed by an interim Phase 2 report and a final report on the results of the study.

The Service's activities in Phase 1 include the following:

1. An inventory of existing flood management systems in the 17 upstream watersheds identified in the 1980 Plan as having significant flood damages.

2. Selection and detailed study of 3 of the 17 upstream watersheds to determine existing flood conditions and the effectiveness of any existing flood management systems.

3. A summary of local citizens' responses as expressed in meetings held in each of the three watersheds and in the Citizens Advisory Group's public forums relating to the watersheds.

4. A discussion of criteria and procedures used in evaluating historic and potential flood losses in the three upstream watershed projects.

INVENTORY OF WATERSHEDS

The original Connecticut River Basin Study identified 17 small watersheds in its early action plan. The New England River Basins Commission called for supplemental study to reevaluate recommended plans and existing flood management systems in these watersheds. The watersheds are shown in figure 1.

The inventory included a review of literature and existing studies, map studies, field checks, and interviews. A detailed description of the inventory procedure is contained in attachment 1 of the "Plan of Work". A summary of the types and extent of existing flood management measures is given below and in table 1.

The watershed inventory identifies those existing measures (structural, nonstructural and natural storage) which provide some degree of protection. Each of these measures is employed to some degree in all of the watersheds, but the level of protection provided is generally low.

Dams

There are 10 flood protection dams located in the 17 watersheds. Five are in the Black River watershed, including the North Springfield reservoir and four structures on the Jewell Brook tributary. The North Springfield reservoir provides protection for Springfield, Vermont, and the area downstream on the Connecticut River. The Jewell Brook dams, completed in 1973, provide 100-year protection along Jewell Brook which joins the Black River in Ludlow, Vermont.

Four dams have been constructed in the Upper Quaboag watershed in Massachusetts as part of a watershed project. The project is now being reformulated and will provide a 100-year level of protection along the Upper Quaboag and several of its tributaries in the towns of Spencer, East Brookfield, Brookfield, West Brookfield, and Warren.

In New Hampshire, the Sugar River watershed has flood storage incorporated into Eastman Pond, a private recreation lake, and in Sunapee Lake in which the State controls water levels. Also in New Hampshire, the Indian-Mascoma watershed has incidental flood storage in several State-operated lakes.

Local Protection Measures

Local protection has been established in many of the watersheds. Individuals, towns and State government, with the assistance of the Corps of Engineers and the Soil Conservation Service, have constructed several measures in the watersheds. Some of these measures are listed below.

Mohawk River, New Hampshire. The lower reaches of the channel have been relocated and enlarged to alleviate ice-jam flooding in Colebrook. Riprap protection of streambanks within the developed area of Colebrook controls the cutting action of the river.

Gale River, New Hampshire. The channel has been enlarged in Franconia.

Indian-Mascoma, New Hampshire. Channel work has reduced flooding of school property in Canaan. A dike protects residential and commercial property in West Canaan.

Sugar River, New Hampshire. In Claremont, a dam has been lowered to reduce flooding of recreation fields at Monadnock Park.

Passumpsic River, Vermont. A 500-foot long dike along the East Branch protects a mobile home park in Lyndon. In St. Johnsbury, a dam has been removed and the channel enlarged to protect residential and industrial property.

Wells River, Vermont. Diking in Ryegate protects industrial property; in Wells River protection is provided to commercial property.

Black River, Vermont. A diversion channel in Ludlow protects residential property.

Mill River, Massachusetts. A diversion channel and dike protect residential and commercial property in Northampton. A dike protects a recreation area at Look Park in Northampton.

Upper Quaboag, Massachusetts. A floodwall and channel through West Warren was built to protect an industrialized section of town. Also, a floodwall constructed as part of the watershed project protects a small industrial-commercial area in Spencer.

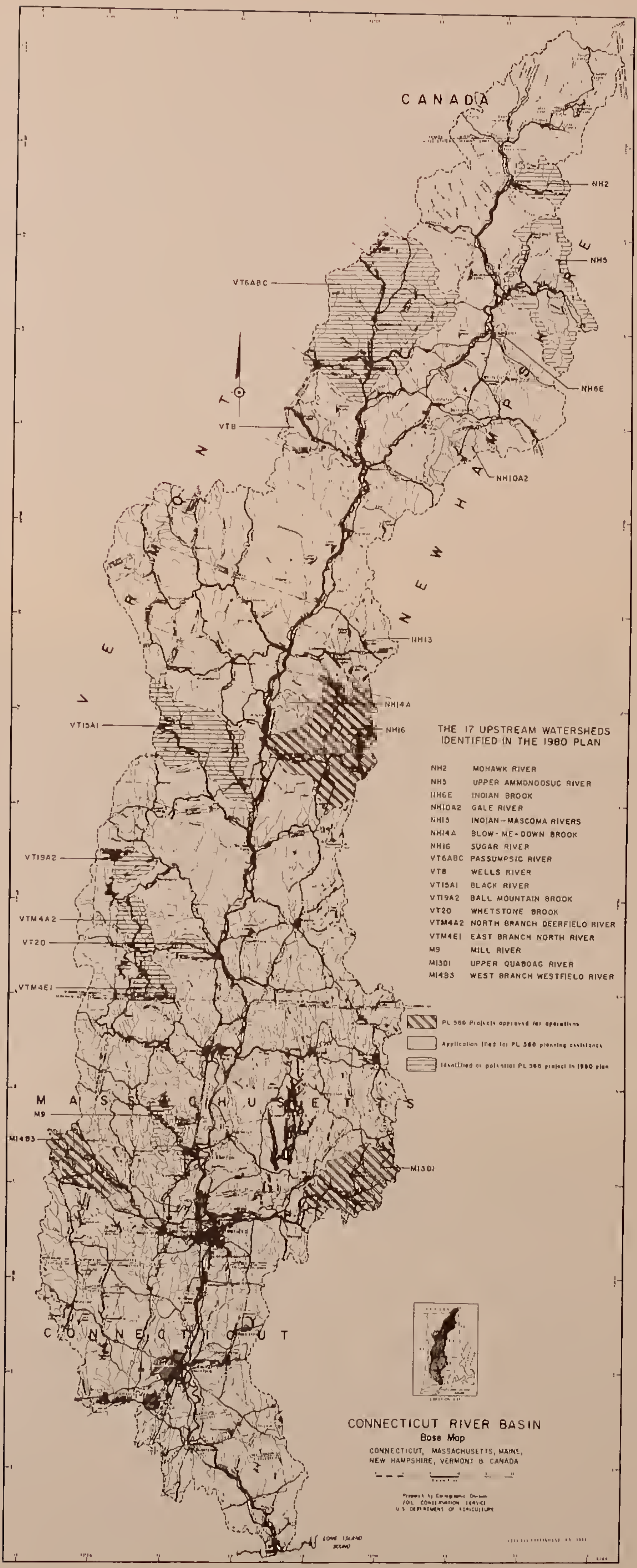

CANADA
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
NH2
NH5
VT6ABC
NH6E
VT8
NH10A2
NH13
NH14A
NH16
VT15A1
VT19A2
VTM4A2
VT20
VTM4E1
M9
M14B3
M1301
THE 17 UPSTREAM WATERSHEDS IDENTIFIED IN THE 1980 PLAN
NH2 MOHAWK RIVER
NH5 UPPER AMMONOOSUC RIVER
NH6E INDIAN BROOK
NH10A2 GALE RIVER
NH13 INDIAN - MASCOMA RIVERS
NH14A BLOW - ME - DOWN BROOK
NH16 SUGAR RIVER
VT6ABC PASSUMPSIC RIVER
VT8 WELLS RIVER
VT15A1 BLACK RIVER
VT19A2 BALL MOUNTAIN BROOK
VT20 WHETSTONE BROOK
VTM4A2 NORTH BRANCH DEERFIELD RIVER
VTM4E1 EAST BRANCH NORTH RIVER
M9 MILL RIVER
M1301 UPPER QUABOAG RIVER
M14B3 WEST BRANCH WESTFIELD RIVER
PL 566 Projects approved for operations
Application filed for PL 566 planning assistance
Identified as potential PL 566 project in 1980 plan
LONG ISLAND SOUND
CONNECTICUT RIVER BASIN
Base Map
CONNECTICUT, MASSACHUSETTS, MAINE, NEW HAMPSHIRE, VERMONT & CANADA
SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

FIGURE 1.

TABLE 1
WATERSHED INVENTORY

WATERSHED	Drainage Area Ac.	Natural Storage			Existing Protection Measures							
		Lakes Ponds Ac	Marsh Ac	Flood Plain Ac	Dams	Dike Etc.	Chan. Work	Flood Proof	Flood Plain Zoning	Warn & Evac.	Flood Ins.	Acquis-ition
NH-2, Mohawk	35,840	100	540	300			x	x		x		
NH-5, Upper Ammonoosuc	162,560	740	2,060	1,200				x		x		
NH-6E, Indian	1,440		100	50				x		x	x	
NH-10A2, Gale	58,240	110	130	800			x	x	x	x		
NH-13, Indian-Mascoma	85,500	2,900	1,200	2,000		x	x	x		x		
NH-14A, Blow-Me-Down	18,110	40		680			x	x		x		
NH-16, Sugar	176,000	6,350	1,200	950	1		x	x	x	x		x
VT-6A,B,Passumpsic	239,360	735	2,000	5,220		x	x	x	x	x		
VT-8, Wells	63,810	790	1,040	750		x		x	x	x		x
VT-15A1, Black	124,800	650	1,000	1,700	5		x	x		x		
VT-19A2,Ball Mountain	22,400	10	5	150				x		x		
VT-20, Whetstone	17,920	50	100	240		x	x	x	x	x	x	
VTM-4A2,N.Br.Deerfield	32,000	180	25	580		x		x	x	x	x	
VTM-4E1,E.Br.North	24,960	56	25	140				x		x		
M-9, Mill	37,760	250	700	500		x	x	x		x	x	x
M-13D1,Upper Quaboag	94,340	4,516	6,100	1,500	4	x	x	x	x	x		x
M-14B3,W.Br.Westfield	60,800	425	1,600	1,010		x		x		x		

Many private and local efforts have resulted in channel cleanout and small diking projects throughout the basin to provide protection. These measures provide only a low level of protection.

Floodproofing

These measures are difficult to inventory. It is nearly impossible to locate all instances of basement waterproofing and structural modifications or to identify filled areas after they are well-established. However, field visits and interviews indicate that floodproofing provides some protection in every watershed.

Flood Plain Zoning

There are nine towns which have implemented flood plain zoning--Lisbon, New Hampshire (Gale River); Newport, New Hampshire (Sugar River); Kirby, Lyndon, and St. Johnsbury, Vermont (Passumpsic River); Newbury, Vermont (Wells River); Marlboro, Vermont (Whetstone Brook); Wilmington, Vermont (North Branch Deerfield); and West Brookfield, Massachusetts (Upper Quaboag River). Zoning ordinances are under consideration or development in several other towns.

HUD Flood Insurance

Four communities (Lancaster, New Hampshire; Brattleboro, Vermont; Wilmington, Vermont; and Northampton, Massachusetts) have been accepted into the HUD national flood insurance emergency program. After completion of flood hazard boundary maps and rate studies, the communities will be eligible for the regular program.

Warning and Evacuation

Established procedures exist in every watershed although the degree of organization and the actual procedures used vary considerably. Most towns rely on civil defense and police and fire departments. The city of Northampton, Massachusetts has created a flood emergency board and written a flood emergency plan. The local communities rely on warnings issued by the National Weather Service and supplement these by local observations and experience.

Public Acquisition - Open Space Program

Public acquisition of flood plain lands, while minimal has occurred principally for the extension or enhancement of recreation and wildlife areas. For example, the city of Claremont, New Hampshire, recently acquired 14 acres of land in the Sugar River flood plain and added it to Monadnock Park. The West Brookfield, Massachusetts Conservation Commission purchased six acres of flood plain to preserve a wildlife marsh.

Subdivision Regulations

The four states within the Connecticut Basin have enabling laws which permit local governments to adopt subdivision regulations which could reduce damage from flooding problems. However, few towns have implemented such provisions and many of the towns have no subdivision regulations at all. Of the more than 60 towns which have substantial land area in the 17 watersheds, only 19 reported subdivision regulations.

On the state level, Vermont closely regulates development by requiring permits. Act 250 of the Vermont Laws of 1970 (Environmental Control Law) empowers the State to control all subdivisions of ten lots or more, as well as many other forms of development. This is done through the State Environmental Board and seven district commissions. The State Board of Health has also adopted subdivision regulations in the interest of public health and requires some minimal protection from flood hazards. In New Hampshire, the Water Supply and Pollution Control Commission reviews plots for adequate waste disposal systems.

Building Codes

Towns in the basin report little use of building codes to reduce flood damage potential of flood plain development. However, the town of Brattleboro, Vermont recently required a lumber company to build its structures to minimize potential flood damage.

Wetland Protection

Massachusetts protects inland wetlands under the Hatch Act of 1965 and the Inland Wetlands Act of 1968. The Hatch Act requires developers to apply for permits to alter inland wetlands. The

State may impose such conditions as "essential to public or private water supply or to proper flood control". The Inland Act affords additional protection to wetlands, but restrictions prevent the State from regulating flood plains.

Other

The search for other measures revealed nothing. There were no reports of other land use policies, warning signs, or tax adjustments that would result in preventing flood plain development.

Natural Storage

Some natural storage exists in every watershed, although in some it is negligible. While the effects of this storage on peak flows is considerable in some watersheds such as the Indian-Mascoma, Upper Quaboag, and Upper Ammonoosuc, this is not an indication of the flood protection provided, as flood damage figures reveal. (Just as in watersheds with no natural storage, flood damages will occur if the flood plain is encroached upon.)

SELECTION AND EVALUATION OF THREE WATERSHEDS

Of the 17 upstream watersheds identified in the 1980 Plan, 3 were selected for further study. Two watersheds were selected early in the study by the Soil Conservation Service and the Bureau of Sport Fisheries and Wildlife. The Citizens and Science Advisory Groups and the Study Management Team concurred with the selection. The watersheds selected were Whetstone Brook and Passumpsic River, both in Vermont. The early selection of these two was made to allow the two agencies to meet schedules for the completion of Phase 1 of the Supplemental Study. Both watersheds appeared to have sufficient flood damages and environmental concerns to justify further study in Phases 1 and 2.

A procedure was developed to select the third upstream watershed for study. All 17 watersheds were compared and rated in terms of the following categories:

1. Population in the watershed.
2. Number of structures proposed.
3. Planning status.
4. Urban flood damages.
5. Drainage area of the watershed.

The six highest-ranking watersheds were the Passumpsic River, Black River, North Branch of the Deerfield River and Whetstone Brook in Vermont; the Mill River in Massachusetts; and the Indian-Mascoma Rivers in New Hampshire. From this group of six the Citizens and Science Advisory Groups selected the Mill River watershed as the third watershed. The inclusion of the Whetstone and Passumpsic in the list verified the significance of environmental and flood damage impacts in these watersheds.

The procedure used for rating the watersheds is presented in detail as attachment 2 of the "Plan of Work".

An information report was prepared for each of the three watersheds and provided to the Citizens Advisory Group for its public forums. Each report discusses the watershed problems as related to flood damages and flood management systems. Existing flooding conditions were analyzed. Critical damage reaches in each flood plain were evaluated and dollar damages were assigned for various frequency storms. Stage-discharge, stage-damage, discharge-frequency,

and damage-frequency curves were developed for each evaluation reach. The curves for two selected reaches in the flood plains of Whetstone Brook, Mill River and Passumpsic River are included in this report as appendix 1. The procedures for making the economic and hydrologic analyses are described in the Procedures section. The information reports for the three watersheds follow.

INFORMATION REPORT
PASSUMPSIC RIVER BASIN

Description of Watershed

The Passumpsic River Basin is located in northern Vermont, primarily in Caledonia County, with fringes in Washington, Orange and Essex Counties. The basin has a total area of 507 square miles. The area to be analyzed in this study consists of subwatersheds VT6A and VT6B (see figure 2). This is located above St. Johnsbury and totals 374 square miles or 239,360 acres.

The drainage pattern of the watershed is generally fan-shaped. The drainage area converges in two primary areas. The first is a reach in the vicinity of Lyndonville where the East and West Branches of the Passumpsic meet and are joined by Millers Run and South Wheelock Branch. Further downstream in St. Johnsbury the Passumpsic is joined by its largest tributary, the Moose River.

The upland topography in the watershed is steep. Tributary channel slopes vary from very steep to relatively flat. For example, the upper reaches of Miller Run fall at 100 feet per mile and then level off to 6 feet per mile in the lower reaches.

Present land use in the watershed is estimated as follows: 74 percent forest, 20 percent distributed between cropland and pasture, and 6 percent urban and miscellaneous. It is expected that forest use will remain constant in the immediate future while agriculture will decrease and urban use increase.

There are about 735 acres of ponds and lakes in subwatersheds 6A and 6B. These ponds provide a limited amount of flood storage and have a negligible effect on flood flows. There are about 2,000 acres of wetlands in the watershed, but, with the exception of Victory Bog with over 1,000 acres, these are small areas located in the headwaters and have a limited effect on flood flows. Victory Bog provides a significant amount of natural flood storage, but it is not sufficient to prevent floodwater damages from occurring on the lower reaches of the Moose River.

Flooding

Damaging floods have occurred in the Passumpsic River Basin in 1828, 1866, 1869, 1896, 1897, 1913, 1927, 1933, 1935, 1936, 1940, 1950, 1952, 1968, 1969, 1972, and 1973. The 1927 event is the greatest flood on record.

Information on historical floods in the Passumpsic is available from stream gaging stations maintained by the U. S. Geological Survey. The table below presents the flood crests and discharges for the gage at Passumpsic, Vermont.

TABLE 2
FLOOD CREST ELEVATIONS
PASSUMPSIC RIVER GAGE AT PASSUMPSIC (SINCE 1927)

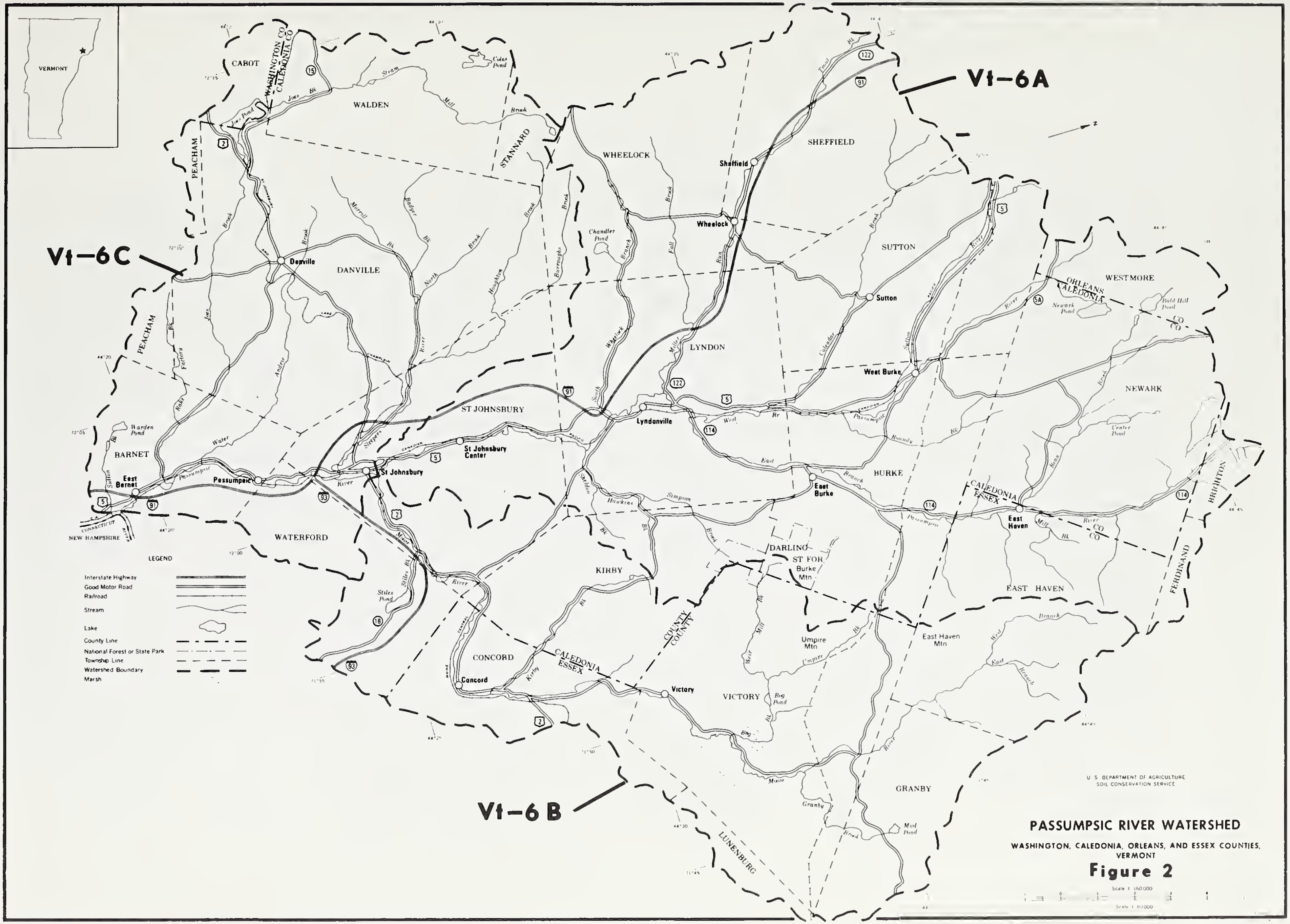
Date of Crest	Elevation at Gage (a) ft msl	Peak Discharge cfs
5 Nov 1927	521.5	42,500 (est)
1 Jul 1973	513.5	18,200
18 Mar 1936	511.2	16,000
10 Jan 1935	507.7(b)	8,500
5 May 1972	506.9	11,900
24 Mar 1938	506.3	11,000 (est)
23 Apr 1954	505.7	10,900
21 Mar 1950	505.6	10,700
24 Mar 1968	505.0(b)	-
19 Apr 1969	504.8(b)	10,000
2 Jun 1952	504.4	9,670

(a) Zero of gage is 490 ft. msl (from topographic map).
(b) Stage due to ice.

Past floods have been described in newspapers, books and historical data. These accounts from the late 1800's and early 1900's describe bridges and buildings being swept away by flood waters. Many times, "the greatest ever known" was used to describe these earlier floods. This has not been necessary following the 1927 flood, which is the greatest flood on record in the Passumpsic. The stages and flows resulting from the 1927 flood are formidable compared to all the rest as shown in table 2. A repeat of the 1927 storm would flood about 400 residences, about 100 businesses and industries, and many other properties and utilities.

The most recent flood occurred on June 30-July 1, 1973. Following is a summary of an article which appeared in the St. Johnsbury Caledonian-Record on July 2, 1973.

Heavy rainfall starting on June 30 culminated a month of record rainfall in St. Johnsbury for the month of June. The 9.65 inches for the month was the highest recorded since records started in 1892. The flood waters caused major damages in Lyndon and St. Johnsbury.



U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

PASSUMPSIC RIVER WATERSHED

WASHINGTON, CALEDONIA, ORLEANS, AND ESSEX COUNTIES, VERMONT

Figure 2

In the Lyndonville area residential and business areas were put under water. In the north end of the village, a service station, motel, restaurant, a mobile home park and sales office, and many homes were hit by several feet of water. South of town several businesses and homes received major damage as water reached a height of four feet over the road. Water levels reached 3½ to 4 feet inside the Shop and Save supermarket and 3 feet in the savings bank branch office. At least eight businesses and dozens of homes were flooded in this area.

St. Johnsbury Center was one of the hardest hit communities in the watershed. Many homes suffered water damage. Silt lines showed that water had reached as high as first floor windows. Pagaeus' Market suffered heavy damage with about four feet of water. The water carried the smell of gas from the flooded pumps at the market.

In St. Johnsbury water from the Passumpsic, Moose and Sleepers Rivers threatened the town. Flooding occurred along South Main, Elm and Drouin Streets. The sewerage treatment plant was flooded and water mains were broken at four bridge locations. Along St. Mary Street water reached the doorsteps of many homes. St. Johnsbury was cut off from the rest of the State except for one-lane traffic along Route 18.

Flooded and washed out roads were common cutting off small communities and stranding many travelers.

The towns of St. Johnsbury and Lyndon are also subject to ice-jam flooding. Jams composed of ice and debris form in the river channel at points where the channel constricts due to ledge outcrops, midstream islands, sharp bends, or sedimentation.

Flood plain studies have delineated over 7,000 acres of flood plain in the Passumpsic watershed. The following tables present estimates of land use within this flood plain area. The information for the towns of St. Johnsbury and Lyndon is based on areas inundated by the 100-year flood and the use of aerial photos.

TABLE 3
FLOOD PLAIN LAND USE
PASSUMPSIC RIVER WATERSHED

Land Use	Acres	Percentage
Agriculture	2,220	32
Woodland and Wetland	3,670	52
Urban	310	4
Miscellaneous	850	12
TOTAL	7,050	100

TABLE 4
FLOOD PLAIN LAND USE
ST. JOHNSBURY AND LYNDON
100-YEAR FLOOD PLAIN

Land Use	St. Johnsbury		Lyndon	
	Acres	Percentage	Acres	Percentage
Water	300	30	170	16
Urban	180	18	100	10
Agriculture	150	15	480	45
Wetlands	250	25	200	19
Miscellaneous	120	12	100	10
	1,000	100	1,050	100

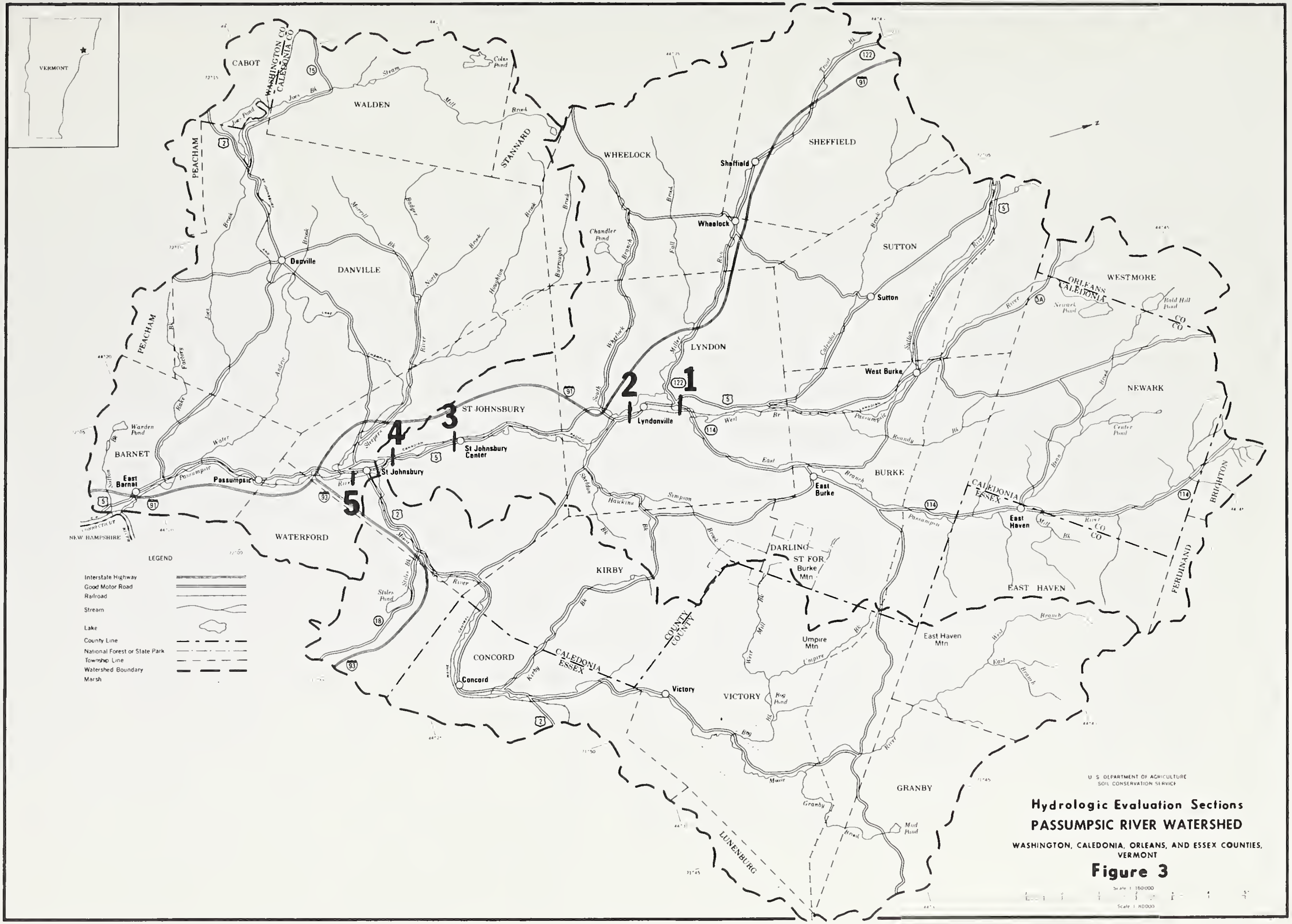
Hydrologic Analysis

The watershed above the stream gage at Passumpsic, Vermont, was analyzed so that a synthetic range of floods could be developed to represent realistically the floods which can be expected to occur with return periods from 5 years to 100 years. An attempt was also made to reconstruct the flows of two actual storms - November 1927 and June-July 1973.

Results of the above study are summarized in table 5 for five evaluation locations shown in figure 3.

Flood Damages

Damaging floods have hit the Passumpsic several times and serious damages have occurred at East Burke, West Burke, Lyndonville, St. Johnsbury Center and St. Johnsbury. The flood plain has attracted considerable development, which is now subject to flooding. Should a major flood occur, transportation damages would be widespread. About 400 residences and 100 businesses would be subject to flooding, primarily in the Lyndonville, St. Johnsbury Center and St. Johnsbury areas. There are also about 2,100 acres of crop and pasture land which would be affected. Specific information for the major reaches is presented in table 8.



Hydrologic Evaluation Sections
PASSUMPSIC RIVER WATERSHED
WASHINGTON, CALEDONIA, ORLEANS, AND ESSEX COUNTIES, VERMONT

Figure 3

Estimates show average annual damages of $539,200 in the watershed (see table 7). This figure reflects direct and indirect damages with an adjustment for future values. The average annual damage is based on direct damages estimated for different frequency events which are shown in table 6. Damages were estimated for reaches shown in figure 4.

TABLE 5
STAGE-DISCHARGE-FREQUENCY RELATIONSIPS
PASSUMPSIC RIVER WATERSHED

Location Along Passumpsic River	Drainage Area Sq.Mi.	Estimated Maximum Flow (cubic feet per second) and Depth (feet) over Low Flood Plain 1/ 10-year cfs.	ft.	100-year cfs.	ft.	1927 2/ cfs.	ft.	1973 3/ cfs.	ft.
1. Lyndonville North	150	7,220	3.4	17,310	7.5	19,100	8.0	11,550	5.4
2. Lyndonville South	200	10,470	8.2	25,620	15.9	26,720	16.4	15,160	10.6
3. St.Johnsbury Center	240	12,040	4.2	28,820	11.0	32,000	12.0	16,840	6.8
4. St.Johnsbury, North of Moose R.	247	12,170	-0.5	29,050	5.6	32,470	6.6	16,800	1.5
5. St.Johnsbury South of Moose R. (Loop Area)	374	15,000	1.1	35,250	7.1	43,120	9.1	21,170	3.2

1/ Low flood plain is that portion of the flood plain covered by the greatest depth of water during a flood.
2/ The 1927 is largest flood in recorded history of Passumpsic. Seven inches of rain fell in less than a 2-day period with 4.2 inches falling in 12-hour period.
3/ The 1973 flood is the largest flood since 1927, with 4.1 inches of rain falling in 30-hour period.

TABLE 6
SUMMARY
ESTIMATED DIRECT AND INDIRECT FLOOD DAMAGES
PASSUMPSIC RIVER WATERSHED
($1,000)1/

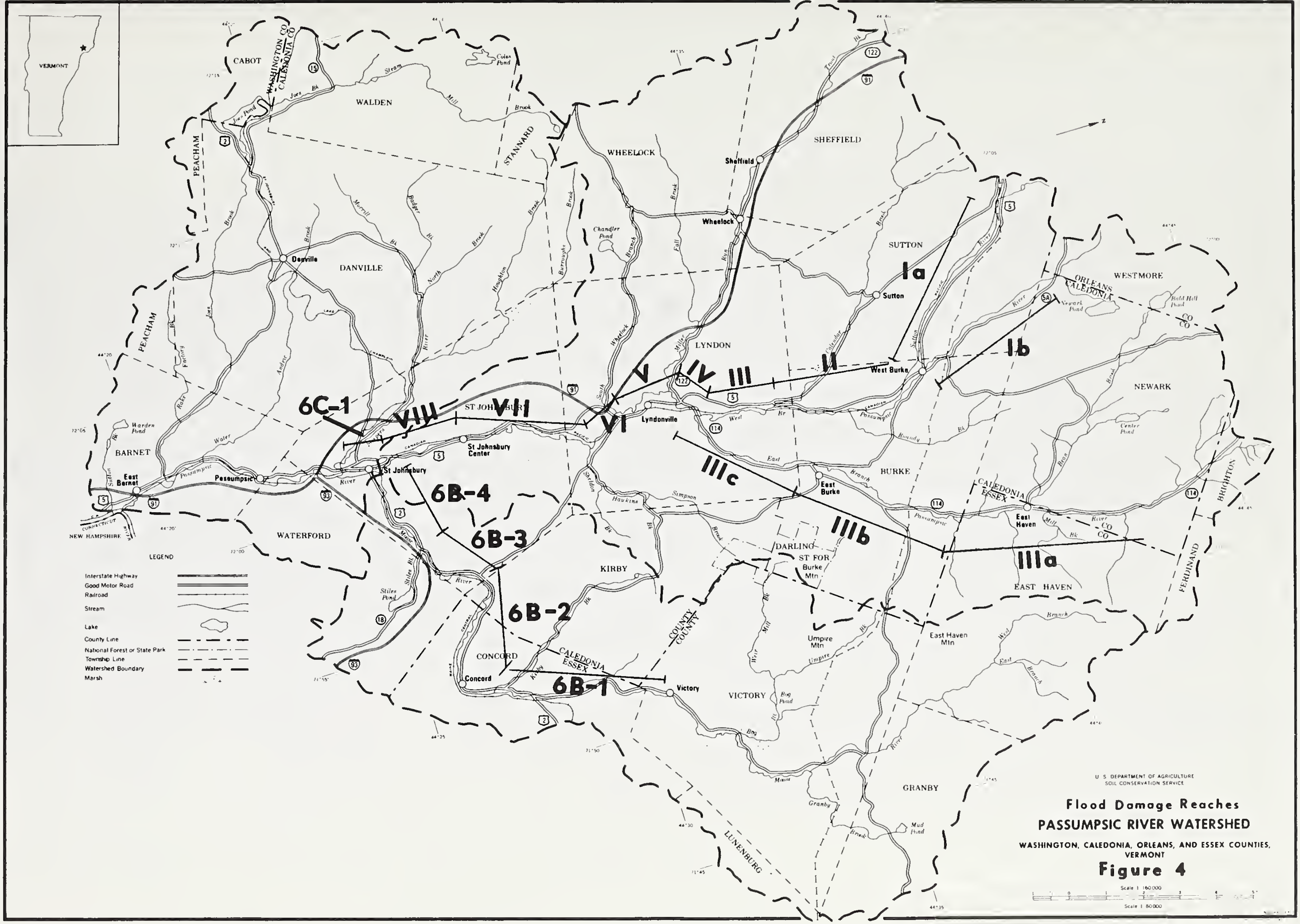
Reach of Stream	Chance of Occurrence 1% (100 yr)	2% (50 yr)	4% (25 yr)	10% (10 yr)	Single Flood Events 1927	1973
IV	575	501	430	143	575	430
V	1,140	670	210	15	1,213	90
VII	1,335	1,050	500	75	1,433	400
VIII	410	210	85	0	570	62
6C-1	1,321	784	285	104	1,940	285
Other	1,749	1,135	331	75	2,032	331
Total Direct	6,530	4,350	1,841	412	7,763	1,598
Indirect (15%)	980	652	276	62	1,164	240
Total	7,510	5,002	2,117	474	8,927	1,838

1/ Price Base: 1973. Does not include future values.

TABLE 7
AVERAGE ANNUAL DAMAGES1/
PASSUMPSIC RIVER WATERSHED
(Dollars)

Urban	286,100
Roads and Bridges	154,700
Agriculture	28,100
Total Direct	468,900
Indirect (15%)	70,300
Total	539,200

1/ Price Base: 1973. Includes future values.



U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Flood Damage Reaches
PASSUMPSIC RIVER WATERSHED
WASHINGTON, CALEDONIA, ORLEANS, AND ESSEX COUNTIES, VERMONT

Figure 4

Scale 1:160 000
Scale 1:80 000

TABLE 8
FLOOD PLAIN DEVELOPMENT SUSCEPTIBLE TO FLOOD DAMAGE
PASSUMPSIC RIVER WATERSHED

Reach	Reach Description	Road	Rail-road	Bridges Culverts etc.(No.)	Residences (Number)	Commercial & Industrial (Number)	Agric. Land (acres)	Other
Ia	Sutton River	x	x	8	6	2	300	
Ib	W.Br.Pass. to W.Burke	x		7	6	2	200	
II	W.Br.Pass. to Calendar Brook	x	x	3	20		110	
IIa	Calendar Brook	x		7	25		60	
III	W.Br.Pass. to conflu. W/E Br.		x	x			20	
IIIa	E.Br.Pass.to gage station	x		5			30	Pumphouse
IIIb	E.Br.Pass.-gage to E.Burke	x		x			180	
IIIc	E.Br.Pass. - E.Burke to conflu. w/W.Br.	x		2	10		230	Highway barn
IV	Passumpsic-Lyndonville North	x	x	2	108	3	40	Covered bridge, Ball Park
IVa	Upper Miller Run	x		8	6		270	
IVb	Lower Miller Run	x		3	6		140	
V	Passumpsic-Lyndonville South	x	x		21	18	120	Elem. School
Va	South Wheelock Branch	x		x	6		30	
Vb	Passumpsic - Lyndon				15		30	
VI	Passumpsic - S.Wheelock Br. to Sheldon Brook	x	x		10	2	80	Hydroelec.plant
VIa	Sheldon Brook	x		x	10		80	
VII	Passumpsic - St.Johnsbury Center	x	x	x	80	26	120	2 Hydroelec. plants
VIII	Passumpsic - St.Johnsbury North	x	x		34	24	30	Hydroelec.plant
6C-1	Passumpsic - Moose R. to Sleepers R. - "Loop Area"	x	x		44	14		Sewerage treatmen[t] plant, rec.area
	TOTALS				407	91	2,070	

Note: "x" denotes that development occurs in the specific reach.

Existing Flood Management Systems

Even after many flooding occurrences, the developed area in the flood plain remains relatively unprotected. Some areas receive some flooding on an annual basis, and a ten year event will cause widespread flooding and significant damages. Steps have been taken to prevent future flood plain development and damages. There is a lack of data relating to the costs of any measures and the resulting monetary benefits; therefore, only a description can be presented.

The towns of Lyndon and St. Johnsbury have received flood plain information studies and have adopted flood plain zoning. The Corps of Engineers prepared the flood plain information study for St. Johnsbury. The report delineates flood plains on about nine miles of the Passumpsic and 5.5 miles of the Moose River. In the town of Lyndon, the Soil Conservation Service prepared a flood hazard analysis covering about 10 miles of the Passumpsic, 3 miles of the East Branch, 4.3 miles of Miller Run and 0.8 mile of South Wheelock Branch. The reaches covered in the reports are shown in figure 5.

The town of St. Johnsbury uses the Corps of Engineers' report as its guide in zoning the flood plain which includes about 1,000 acres of land with 100-year flood level susceptibility. In Lyndon, zoning laws regulate development and landfill requirements in an area approximating the 20-year flood plain. This involves about 800 acres in the town.

The zoning ordinance in St. Johnsbury could stem the increase of flood damages in the town effectively. Zoning in Lyndon is less effective as four feet of water has flowed over some areas already filled to about the 20-year storm level. Zoning effectiveness in both towns will depend upon the enforcement of the regulations as only 15 percent of the flood plain is developed.

Very few measures to protect existing properties have been installed in the watershed. Some stretches of roads and railroads on the flood plain are located above frequent flooding levels. However, some flooding still occurs along the major roads. This is critical since flooding results in detours and stranding of motorists.

A mobile home park owner in Lyndon constructed a 500-foot dike along the Passumpsic to a level that was within 6 inches of the 100-year flood elevation. About 50 mobile homes are in the park. The protection in this case may be questionable because of abuses and lack of maintenance of the dike. Also, the dike stops at the property line and is not tied in to high ground. Therefore, water can flow around the dike from either end. During the July 1973 flood, flood waters entered the park and caused minor water damage to many of the mobile homes. Other damage was averted because several of the homes were moved to higher ground.

Over the past years landowners in the watershed have applied land treatment measures with technical assistance provided by the Soil Conservation Service. The more common measures applied and the estimated extent of these measures appears in the following table.

TABLE 9
LAND TREATMENT MEASURES
PASSUMPSIC RIVER WATERSHED

Measure	Quantity
Hay and Pasture Land Management	6,000 acres
Grassed Waterways	20 acres
Tile	200,000 feet
Ponds	190 units
Brush Control	500 acres
Critical Area Planting	100 acres
Spring Development	130 units
Clearing and Snagging Along Streams	14,000 feet
Stream Channel Stabilization	2,000 feet
Streambank Protection	5,000 feet
Conservation Cropping	800 acres

These measures were applied to reduce erosion and sediment and to conserve the soil and water resources. Although peak flow control was not a goal of these measures, some gains may be realized.

At present, about 75 percent of the land in the basin is forested. The hydrologic condition of the watershed in terms of the ability of the soil to absorb and hold water is generally fair.

Conclusions

Damaging floods have hit the Passumpsic with devastating regularity. The severity of recent events has adequately and somewhat rudely warned basin residents of the damages and inevitable results of inhabiting the flood plain. The future will tell whether these warnings are heeded.

Unlike some watersheds which have not experienced a major flood in recent years, the Passumpsic has had several. The problem is recognized and some residents would like to seek a solution. Citizens attending a September 1973 meeting expressed a desire to deal with the problem, asked questions about current policies and events, and suggested solutions to the flooding problem.

In dealing with the flooding problems in the Passumpsic and attempting to formulate a flood management plan, some basic questions need to be considered. Questions dealing with the occupancy of the flood plain by man; the concept that the flood plain belongs to the river; the problem of what can be done for current development in the flood plain in Lyndonville, St. Johnsbury Center and St. Johnsbury, and other areas; the problem that structural solutions to current flooding problems often result in increased use of the flood plain and increased damages; and others must be discussed.

In any case, one group, whether it represents the flood-endangered residents, economic interests, environmental interests, or whatever, cannot decide by itself what the needs of the basin are. Without adequate communication and participation in the early planning stages by all interested groups, any final plan will probably be futile.

INFORMATION REPORT
WHETSTONE BROOK WATERSHED

Description of Watershed

Whetstone Brook is located in Windham County in southeastern Vermont. The brook originates in the town of Marlboro and flows east through the town of Brattleboro to its confluence with the Connecticut River. The Whetstone drains an area of about 28 square miles or 17,900 acres (see figure 6).

Present land use in the watershed is estimated as follows: 6% cropland, 4% pasture, 78% forest, 5% urban and 7% miscellaneous. The proportion of forest land is expected to remain relatively constant over the next 10 to 15 years, while agricultural land will continue to decrease and urban land increase.

The stream gradient is steep, and in ten miles the Whetstone falls over 1,400 feet. The Whetstone is a very flashy stream, capable of reaching peak flows in a few hours. There is very little natural storage within the watershed to retard the flow of the water in the brook.

Flooding

Flooding has occurred in the watershed in 1969, 1927, 1936, 1938, 1955, 1969, and 1973.

The major flood plain area of the watershed is in the town of Brattleboro. This includes the area along Whetstone Brook and the lower reaches of Halladay Brook. The flood plain in this area has been delineated in the flood plain information study prepared for the town by the Corps of Engineers. The breakdown of present land use in this area is estimated in the following table.

TABLE 10
FLOOD PLAIN LAND USE
TOWN OF BRATTLEBORO
WHETSTONE BROOK WATERSHED

Land Use	Acres	Percentage
Urban	130	62
Agriculture	40	19
Miscellaneous	40	19
Total	210	100

Hydrologic Analysis

The Whetstone Brook watershed was analyzed so that a synthetic range of floods could be developed to represent realistically the floods expected to occur with return periods from 5 years to 100 years. An attempt was also made to reconstruct the flows of two actual storms, September 1938 and June-July 1973, and one hypothetical storm, June-July 1973 rainfall at Ball Mountain Lake transposed to Whetstone Brook.

Results of the above study at the four evaluation locations shown in figure 7 are summarized in the following table:

TABLE 11
STAGE-DISCHARGE-FREQUENCY RELATIONSHIPS
WHETSTONE BROOK WATERSHED

Location Along Whetstone Brook	Drainage Area Sq.Mi.	Estimated Maximum flow (cubic feet per second) and Depth (feet) over Low Flood Plain 1/ 5-year cfs.	5-year ft.	100-year cfs.	100-year ft.	1938 2/ cfs.	1938 2/ ft.	1973 3/ cfs.	1973 3/ ft.
1. Confluence of Halladay & Whetstone	16	1,445	1.8	5,225	4.3	4,790	4.1	2,085	2.5
2. Confluence w/Pleasant Valley Brk.	16	1,440	0.3	5,185	5.3	4,770	3.2	2,075	1.1
3. West Brattleboro	25	2,300	0.5	8,215	4.9	7,465	4.5	3,350	1.6
4. Brattleboro	28	2,515	-0.4	8,750	5.4	8,115	5.0	3,600	0.9

1/ Low flood plain is that portion of the flood plain covered by the greatest depth of water during a flood.

2/ The 1938 is the largest flood of this century on Whetstone Brook - 8.76 inches of rain fell in less than a 3-day period with 3.5 inches falling in a 12-hour period.

3/ The 1973 flood varied markedly throughout the state - 5.67 inches of rain fell at Newfane in a 2-day period with 1.55 inches falling in a 3-hour period. However, 10 miles away at Ball Mountain Lake, 7.1 inches of rain fell in 2 days with a two-hour deluge of 3.2 inches. If this burst of rain had hit Whetstone Brook, it would have created flood stages at least 0.3 feet above the 100-year level.

Figure 6
WHETSTONE BROOK WATERSHED
WINDHAM COUNTY, VERMONT

VERMONT
DUMMERSTON
Dummerston Hill
MARLBORO
BRATTLEBORO
Lyman Hill
Marlboro
Ames Hill
Hidden Lake
Whetstone
Molly Brook
Stark Trail
Halladay Brook
Pleasant Valley Reservoir
Richardson Mountain
Round Mountain
Ginseng Hill
Ames Hill
Brook
West Brattleboro
Brattleboro
1
2
3
4
CHESHIRE COUNTY
Connecticut River
NEW HAMPSHIRE
72°40'
72°35'
42°50'
N
LEGEND
Dual highway
Good motor road
State line
Stream
Lake
Township line
Watershed boundary
Railroad
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Hydrologic Evaluation Sections
WHETSTONE BROOK WATERSHED
WINDHAM COUNTY, VERMONT
Scale 1:
4 Miles
SOURCE USGS TOPO SHEETS
October 1973

Figure 7

Flood Damages

Flood damages in the Whetstone Brook watershed occur almost wholly to residential and commercial property. Residences located in threatened areas include semipermanent mobile homes, multiunit housing developments for the elderly, apartment units and single family houses. There are nearly 400 such units on the flood plain.

Flood damages have been estimated for seven reaches shown in figure 8. A description of the damages in each reach is described below.

Reach I. The flood plain in this area is only 100 to 150 feet wide and damages are infrequent. About ten homes, two businesses and roads and bridges are subject to flood waters along this steep portion of the Whetstone.

Reach II. Along the lower reaches of Halladay Brook flood waters of the 100-year flood will partially inundate a mobile home park and a trailer sales business. About 50 mobile homes are involved.

Reach III. Just downstream from its confluence with Halladay, the Whetstone is joined by Pleasant Valley Brook. The water from the 100-year flood will flood the mobile homes along the lower portion of Pleasant Valley Brook, a restaurant, and Route 9. Downstream the waters will inundate several businesses along Route 9. Several residences will also be flooded in the Meadowbrook Road area.

Reach IV. This reach extends a half mile along the Whetstone from its confluence with Ames Hill Brook, to its confluence with Bonnyvale Brook. The 100-year flood in this reach floods a housing project for the elderly and a mobile home park.

Reach V. The major damage area in this reach is Melrose Terrace, an 80-unit housing development for the elderly. The upstream end of this housing area is exposed to the full force of the Whetstone at flood stage. Water has entered and threatened this area during the 1969 and 1973 floods. Downstream, apartments, 10 homes and a mink farm occupy the flood plain.

Reach VI. Along this reach, extending from Herrick Brook down to the Elliott Street crossing, an estimated 14 homes, a plumbing and heating supply and an automotive supply firm are subject to flooding. Otherwise, the reach is mostly undeveloped.

Reach VII. The potential for flood damage is greatest in this reach because it is located in the downtown Brattleboro area. Flood waters from the 100-year event will flood about 40 homes and major shopping and commercial areas.

Other. In addition to the above major damage reaches, flood waters also cause damages to roads and bridges throughout the watershed. Flooding also affects agricultural land and residences along Ames Hill Brook.

A major flood in the watershed would cause about 3 million dollars damage along the major reaches of the watershed. It is estimated that the 1973 flood caused damages of $150,000. Table 12 presents direct flood damages for the major flood damage reaches. The direct damage figures reflect the current status of the flood damage situation. The table also presents indirect damages, considered to be 15 percent of direct damages. These damages include lost work time, interruption of services, increased travel required because of impassable roads and bridges, and other similar factors.

The average annual damage for the watershed is $226,800. This figure reflects an adjustment for future values which assumes that property values will increase.

Monetary damage figures do not reflect the grief and misery floods create, especially for the many people living at streamside who lose their homes, belongings and perhaps their lives.


72°40'
72°35'
VERMONT
DUMMERSTON
Dummerston Hill
Hidden Lake
Whetstone
Halladay
Brook
Pleasant Valley Reservoir
II
MOLLY
Brook
STARK
TRAIL
Richardson Mountain
MARLBORO
I
9
BRATTLEBORO
Lyman Hill
Marlboro
Round Mountain
III
West Brattleboro
IV
Ames Hill
Hill
Ames
Brook
Ginseng Hill
V
VI
VII
Brattleboro
91
5
CHESHIRE
CONNECTICUT
RIVER
COUNTY
NEW HAMPSHIRE
42°50'
LEGEND
Dual highway
Good motor road
State line
Stream
Lake
Township line
Watershed boundary
Railroad
N
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Flood Damage Reaches
WHETSTONE BROOK WATERSHED
WINDHAM COUNTY, VERMONT
4 Miles
Scale
October 1973

Figure 8

TABLE 12
SUMMARY
ESTIMATED DIRECT AND INDIRECT FLOOD DAMAGES
WHETSTONE BROOK WATERSHED
($1,000)1/

Reach of Stream	Chance of Occurrence 1% (100 yr)	2% (50 yr)	4% (25 yr)	10% (10 yr)	Single Flood Events 1938	1973
I	70	52	30	10	62	10
II	80	65	37	15	75	15
III	250	170	100	30	248	30
IV	230	155	55	0	200	0
V	300	150	60	15	240	10
VI	190	90	32	5	160	5
VII	1,520	980	600	40	1,350	40
Roads-Bridges All Reaches	190	100	75	20	175	20
Total Direct	2,815	1,762	1,366	135	2,510	130
Indirect (15%)	422	264	205	20	377	20
Total	3,237	2,026	1,571	155	2,887	150

1/ Price Base: 1973. Does not include future values.

TABLE 13
AVERAGE ANNUAL DAMAGES 1/
(Dollars)

Urban	$183,300
Roads and Bridges	13,900
Agriculture	(minor)
Total Direct	197,200
Indirect (15%)	29,600
Total	226,800

1/ Price Base: 1973. Includes future values.

Existing Flood Management System

As mentioned above, a major flood on the Whetstone could cause serious damages in the town of Brattleboro. There are no structural measures within the watershed to protect flood plain residents and development from a large flood. The town presently relies on a flood warning system to prevent loss of life and a flood plain information study and local regulations to control additional development. There is no data to specify costs and benefits of any measures; therefore, only a description will be presented.

The Corps of Engineers has prepared a flood plain information study for the town of Brattleboro. The report outlines about 210 acres of flood plain area susceptible to flooding during the Intermediate Regional or 100-year flood. The extent of the study is shown in figure 9. The information is available from the town.

Brattleboro has not implemented any flood plain zoning regulations but it does maintain some control over flood plain development. Town officials point out flood hazard areas to potential developers and if construction is scheduled for a flood-prone area, reasonable floodproofing measures are required. The town has Act 250[1/] procedures, building codes, site plan approval requirements and subdivision regulations to support its position.

If a structure can be adequately floodproofed, building permits for development in the flood plain are generally allowed. A lumber company in the lower reach of Whetstone Brook has requested a permit to construct kiln drying facilities in the flood plain. The firm will minimize damage potential through overhead electric wiring, elevating electric motors above the floor, orienting kilns in the direction of flow and diking.

A variety of measures exist in the watershed which provide protection against the very frequent smaller storms. Channel cleanout and the resulting spoil banks have restored channel capacity from the effects of sedimentation. A retaining wall has been installed at the upstream end of the Melrose Terrace Housing Project. This does not provide flood protection specifically, but it does provide streambank protection.

1/ Act No. 250 of the Vermont Laws, 1970 Environmental Control Law. The act creates an Environmental Board and District Commissions to regulate development.

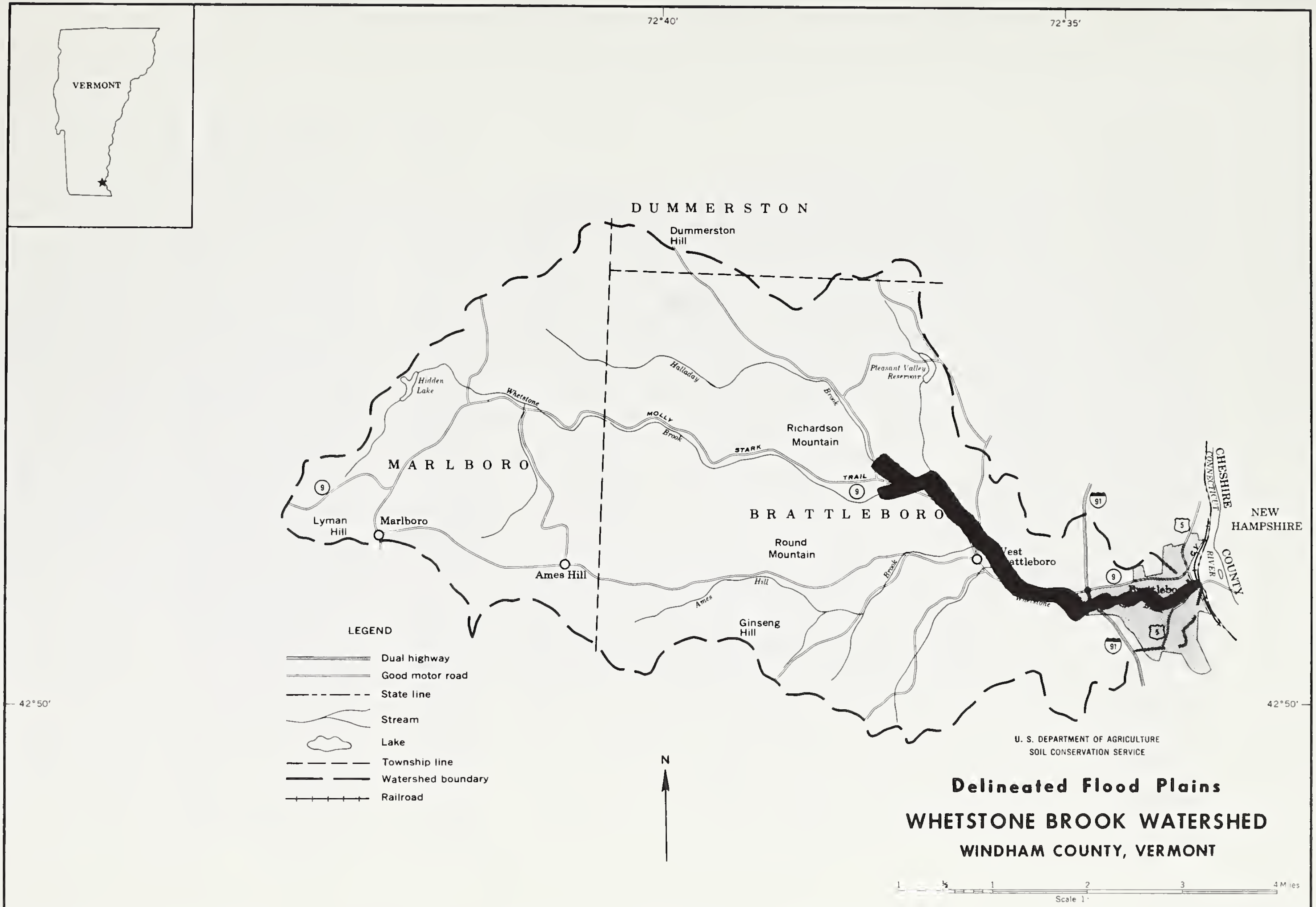

VERMONT
DUMMERSTON
Dummerston Hill
MARLBORO
BRATTLEBORO
Hidden Lake
Pleasant Valley Reservoir
Halladay Brook
Whetstone
MOLLY Brook
STARK
TRAIL
Richardson Mountain
Round Mountain
Ginseng Hill
Lyman Hill
Marlboro
Ames Hill
Ames Hill Brook
West Brattleboro
CHESHIRE
COUNTY
CONNECTICUT
RIVER
NEW HAMPSHIRE
72°40′
72°35′
42°50′
LEGEND
Dual highway
Good motor road
State line
Stream
Lake
Township line
Watershed boundary
Railroad
N
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Delineated Flood Plains
WHETSTONE BROOK WATERSHED
WINDHAM COUNTY, VERMONT
Scale 1″
4 Miles
October 1973

Figure 9

Over the past years landowners in the watershed have installed various land treatment measures to conserve the soil and water resources of their lands. The more common measures applied and the estimated extent of these measures appears in the following table:

TABLE 14
LAND TREATMENT MEASURES
WHETSTONE BROOK WATERSHED

Measure	Quantity
Woodland Improvement	
Clear Cutting	600 acres
Selective Cutting	400 acres
Access Road	2,000 feet
Conservation Cropping Systems	500 acres
Critical Area Planting	15 acres
Diversion	5,000 feet
Drain	5,280 feet
Drainage Main or Laterals	500 feet
Fishpond Management	5 units
Land Smoothing	10 acres
Livestock Exclusion	20 acres
Mulching	25 acres
Pasture and Hay Land Management	1,367 acres
Pond	20 units
Spring Development	5 units
Stripcropping	20 acres
Streambank Protection	100 feet

These measures were applied to reduce erosion and sediment and to conserve the soil and water resources. Although peak flow control was not a goal of these measures, some gains may be realized.

There is very little natural or existing storage within the watershed. Hidden Lake and a small marsh immediately downstream provide some flood storage which would be effective during low level flooding. However, the culvert outlets are set in gravel fill and are susceptible to failure if overtopped. This could increase the hazard during a major flood. Incidental flood storage is also available in Pleasant Valley Reservoir, the Brattleboro water supply. However, the reservoir is not effective in reducing flood flows.

Brattleboro has developed a flood warning and evacutation procedure to alert residents in the flood plain. During the 1973 storm the flood warning system worked effectively. The town did not receive an official warning for tributary flooding, but did receive warnings issued by the National Weather Service for high stages on the Connecticut River. Several residents of the Whetstone watershed did report heavy rainfalls and high brook stages. With Civil Defense, police, and fire department units notified, town officials located flood hazard areas from the Corps of Engineers flood plain information study. Emergency units were dispatched to these areas. Several residents in mobile homes along the Whetstone were evacuated. Civil Defense volunteers stayed on duty throughout the flood threat in case worsening conditions required further evacuation of residents. However, conditions did not worsen and the Whetstone subsided before it caused any further problem. Although the warning and evacuation procedure appeared to work effectively, weaknesses exist. Relying on upstream residents to issue warnings of flood potential on a stream as flashy as the Whetstone is dangerous. As for evacuation, one resident said in an interview that he adopted a "wait and see" attitude during the 1973 flood as the water rose toward his mobile home. The water went down however, and the emergency passed.

The town has recently been accepted into the HUD national flood insurance emergency program. This will permit flood plain residents to obtain subsidized flood insurance. It is not known how much development had flood insurance prior to this, but the owner of one mobile home park in the flood plain has provided flood insurance coverage to the park inhabitants.

The town of Brattleboro and other local sponsors are applying for assistance from the Soil Conservation Service under PL-566, the Watershed Protection and Flood Prevention Act. A preliminary report in 1972 identified problems and presented alternative methods to deal with flooding.

The Corps of Engineers has also studied the flooding problem in the town. At the request of the town manager the Corps developed a plan of protection for Melrose Terrace, a housing development for the elderly. A dike and floodwall in this area was estimated to cost $75,000 in 1969.

Conclusions

A considerable amount of information and counsel has been provided to the town of Brattleboro in recent years. Federal agencies have

met and corresponded with the town frequently. The town is aware that its flood hazard situation is dangerous and potentially disastrous. The town has been told by many that it was "lucky it did not get hit by an Agnes" and "lucky it did not get the rainfall that fell over Ludlow" in 1973.

Town officials and residents are attempting to deal with the problem. They have contacted the Corps of Engineers and the Soil Conservation Service for assistance. They have used the flood plain information study to arouse interest and point out flood hazard areas to developers. However, the town has avoided strict flood plain zoning ordinances. Some of the reasons for this are the shortage of developable land, the desire to protect land values on undeveloped flood plain, and the presence of mobile homes and housing units on the flood plain that are already susceptible to flooding.

While the flood hazard in the watershed is serious, it is not hopeless. Rather, there are still options open for dealing with the problem. At this time there are many ideas as to where the solution may lie. Many answers will be needed before decisions can be made. An important factor will be the continued interest of the people.

INFORMATION REPORT
MILL RIVER WATERSHED

Description of Watershed

The Mill River watershed, shown in figure 10, is located in Hampshire and Franklin Counties in Massachusetts. The stream originates in the eastern part of the Berkshire Hills in the towns of Goshen and Conway. It flows through the town of Williamsburg and city of Northampton to its confluence with the Connecticut River at the Oxbow. Mill River was diverted from its original course at a point near Smith College in Northampton down to the Oxbow as a part of a local flood protection project completed in 1941 by the Corps of Engineers.

The watershed encompasses about 59 square miles (37,760 acres). Land use in the watershed is estimated as follows: 74 percent forest, 9 percent cropland, 5 percent pasture, 7 percent urban, and 5 percent miscellaneaous. In the next ten years forest land use is expected to remain constant, agricultural use to decline and urban use to increase.

The upstream portions of the watershed are steep. In about six miles from Highland Lakes to Williamsburg the West Branch falls 900 feet. At Williamsburg it is joined by the East Branch which has similar slopes and by Meekin Brook with slopes over 200 feet per mile. The Mill River below Williamsburg is less steep with a fall of 400 feet in 12 miles.

There are 1,700 acres of flood plain along the Mill River in Northampton and Williamsburg. Of this, about 1,000 acres is part of a common flood plain shared with the Connecticut and Manhan Rivers. This common flood plain is divided about equally between agricultural and wetland use and is not included in the study analysis. Land use in the Mill River flood plain is estimated in the following table:

TABLE 15
FLOOD PLAIN LAND USE1/
MILL RIVER WATERSHED

Land Use	Acres	Percentage
Agriculture	170	24
Urban	140	20
Wetland and Woodland	310	44
Recreation Areas	80	12
TOTAL	700	100

1/ Excluding flood plain common with Connecticut River.

There are about 250 acres of water surface in lakes, ponds, and reservoirs in the watershed. The Highland Lakes, Mountain Street Reservoir, and Roberts Meadow Reservoir are the major bodies of water. Scattered through the watershed are small wetland areas. One major area, the Nungee Swamp, is located in the Beaver Brook drainage area. In total, there is an estimated 700 acres of wetland in the watershed.

Hydrologic Analysis

The Mill River watershed was analyzed so that a synthetic range of floods could be developed to represent realistically the floods which can be expected to occur with return periods from 5 years to 100 years. An attempt was also made to reconstruct the flows of two actual storms - September 1938 and August 1955.

Results of the study at four evaluation locations shown in figure 11 are summarized in the following table:

TABLE 16
STAGE-DISCHARGE-FREQUENCY RELATIONSHIP
MILL RIVER WATERSHED

Location Along Mill River	Drainage Area Sq.Mi.	Estimated Maximum flow (cubic feet per second) and Depth (feet) over Low Flood Plain 1/ 10-year cfs.	ft.	100-year cfs.	ft.	1938 2/ cfs.	ft.	1955 3/ cfs.	ft.
1. West Br. Williamsburg	13	1,495	-3.4	4,065	2.2	3,250	1.5	1,850	-0.8
2. Bridge St. Haydenville	30	3,505	-0.7	9,000	4.5	7,300	3.0	4,300	0.2
3. Vistron Florence	51	5,155	-2.2	13,055	4.1	10,600	3.5	6,300	1.0
4. Gage Station Northampton	53	5,110	2.6	12,865	5.9	10,600	5.1	6,300	3.2

1/ Low flood plain is that portion of the flood plain covered by the greatest depth of water during a flood.

2/ The 1938 is the largest flood of this century on Mill River. 11.6 inches of rain fell at Amherst in less than a 3-day period. 7330 cfs was measured at Haydenville Dam on September 21st. (USGS Water Supply Paper 867)

3/ The 1955 flood varied markedly throughout the state. 7.06 inches of rain fall at Amherst in a 1½-day period with 4.01 inches falling in a 10-hour period. 6,300 cfs was measured at the gaging station on August 19th. (USGS Water Supply Paper 1420)

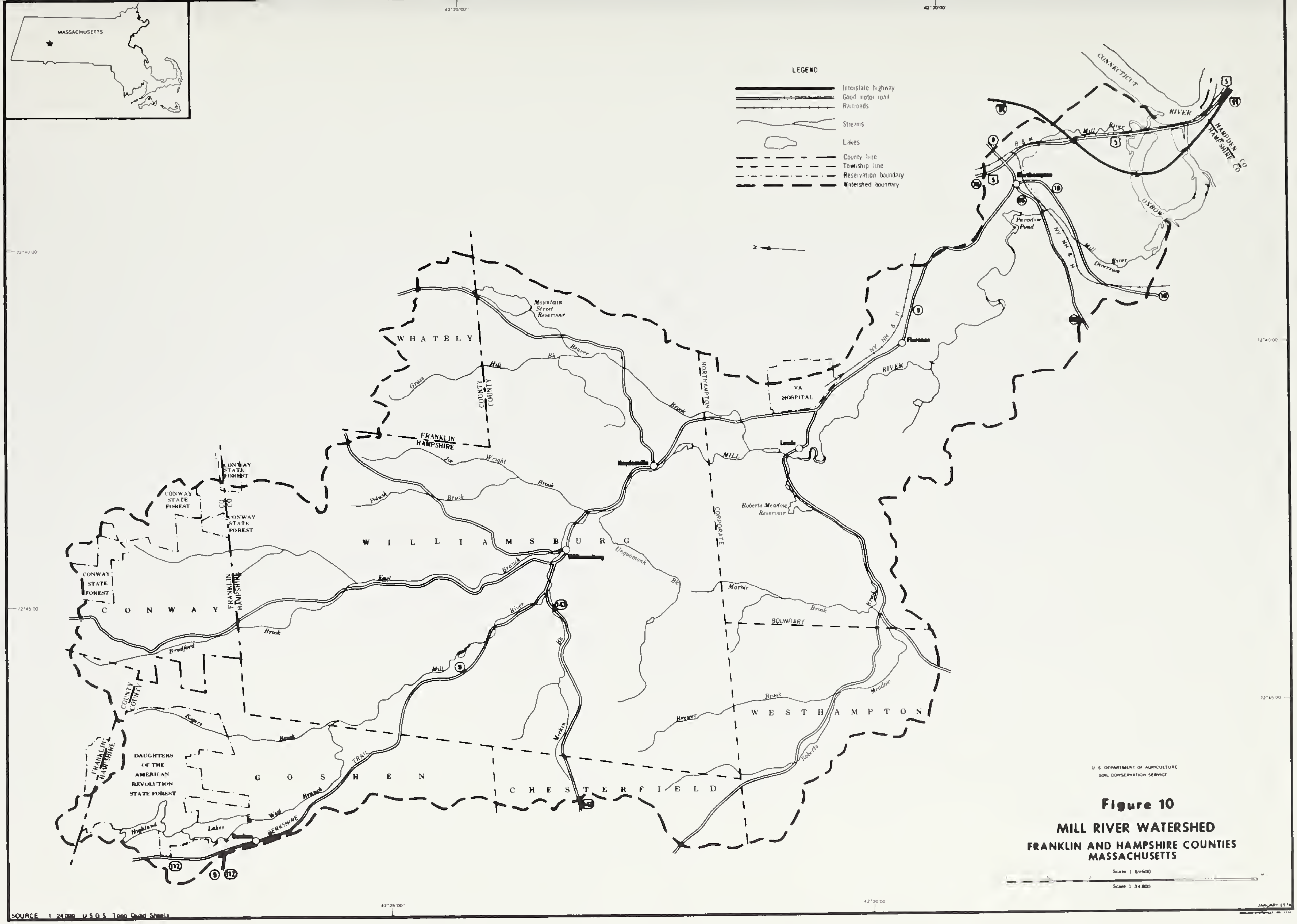
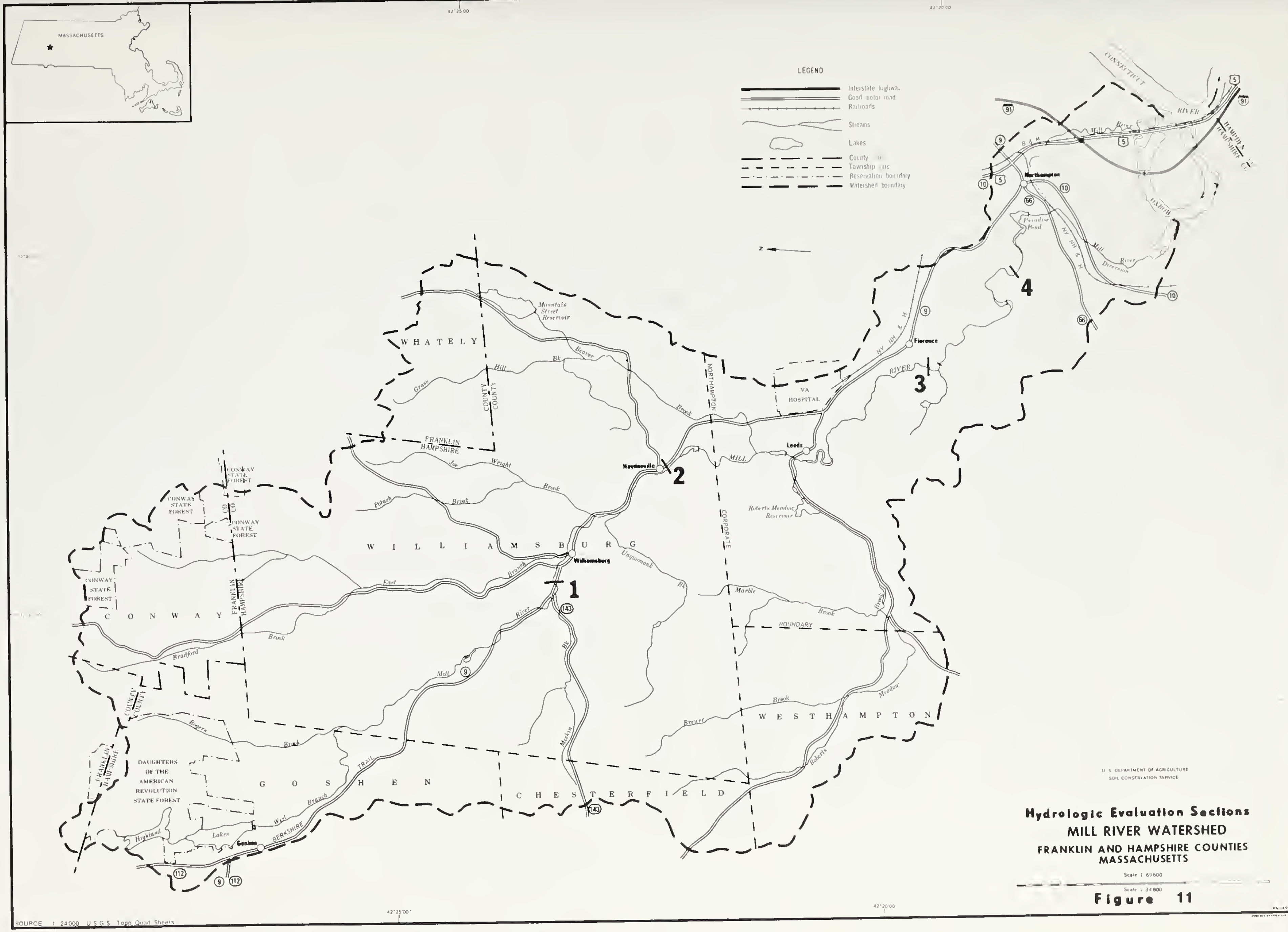


Figure 10

MILL RIVER WATERSHED

FRANKLIN AND HAMPSHIRE COUNTIES
MASSACHUSETTS



Hydrologic Evaluation Sections
MILL RIVER WATERSHED
FRANKLIN AND HAMPSHIRE COUNTIES
MASSACHUSETTS

Scale 1:69600

Scale 1:34800

Figure 11

Flood Damages

Major flooding has hit the Mill River watershed in 1936, 1938, and 1955. The 1938 flood was the largest and caused the most damage. Property susceptible to damage includes about 100 residences, 20 commercial concerns, a major industry and recreational areas. Under present conditions the 100-year flood would result in damages of $1,135,000. Average annual damages are estimated at $64,900. This figure reflects an adjustment for future values which assumes that property values will increase.

Flood damages have been estimated for seven reaches shown in figure 12. A brief description of potential damage in each reach follows:

Reach Ia. Ten houses located along Route 9 are subject to damage from infrequent floods. Most damage would be to basements and grounds.

Reach Ib. In 1938 flood damage occurred to about 25 homes, a car agency, 2 gas stations, a barber shop and 4 retail stores. Water levels ranged from basement flooding to a depth of three feet over first floors of some buildings.

Reach Ic. This reach contains 11 homes and 4 businesses which may be subject to flooding during a major event.

Reach II. Damage in this reach is limited, occurring mostly to the lower elevations of the old brass mill.

Reach III. Flows in excess of the 1938 event would cause basement flooding in 25 homes and small businesses in the Haydenville area. The more frequent floods pass through this reach with minimal damage.

Reach IV. In Leeds about 30 homes are subject to basement flooding. Downstream, Look Park is subject to partial flooding. Damages would result principally from the flooding of picnic facilities, flood plain erosion and costs of clean-up. The Mill River Plantation was flooded during the 1938 and 1955 storms. There were about 50 acres flooded to depths of one to three feet. Barns and tobacco sheds were also flooded.

In Florence, portions of the Prophylactic Brush Company, now Vistron Corporation, are subject to flooding. In 1955 about two feet of water entered the lower elevations of some areas. A floodwall protects much of the plant from greater damage. A new warehouse may be susceptible to damage during major flooding.

Reach V. There are four home basements and one business subject to flooding in this reach.

Other. Damage to roads and bridges occurs throughout the watershed. Also susceptible to flooding are areas of scattered development along tributaries of the Mill River.

At the present time agricultural damage is not significant and is limited to one reach on Mill River. Little agricultural damage is expected to occur in the future since the area known as the Plantation may be developed for urban use. A recurrence of the 1938 equivalent flood will cause additional urban and residential damage to any future development in the area.

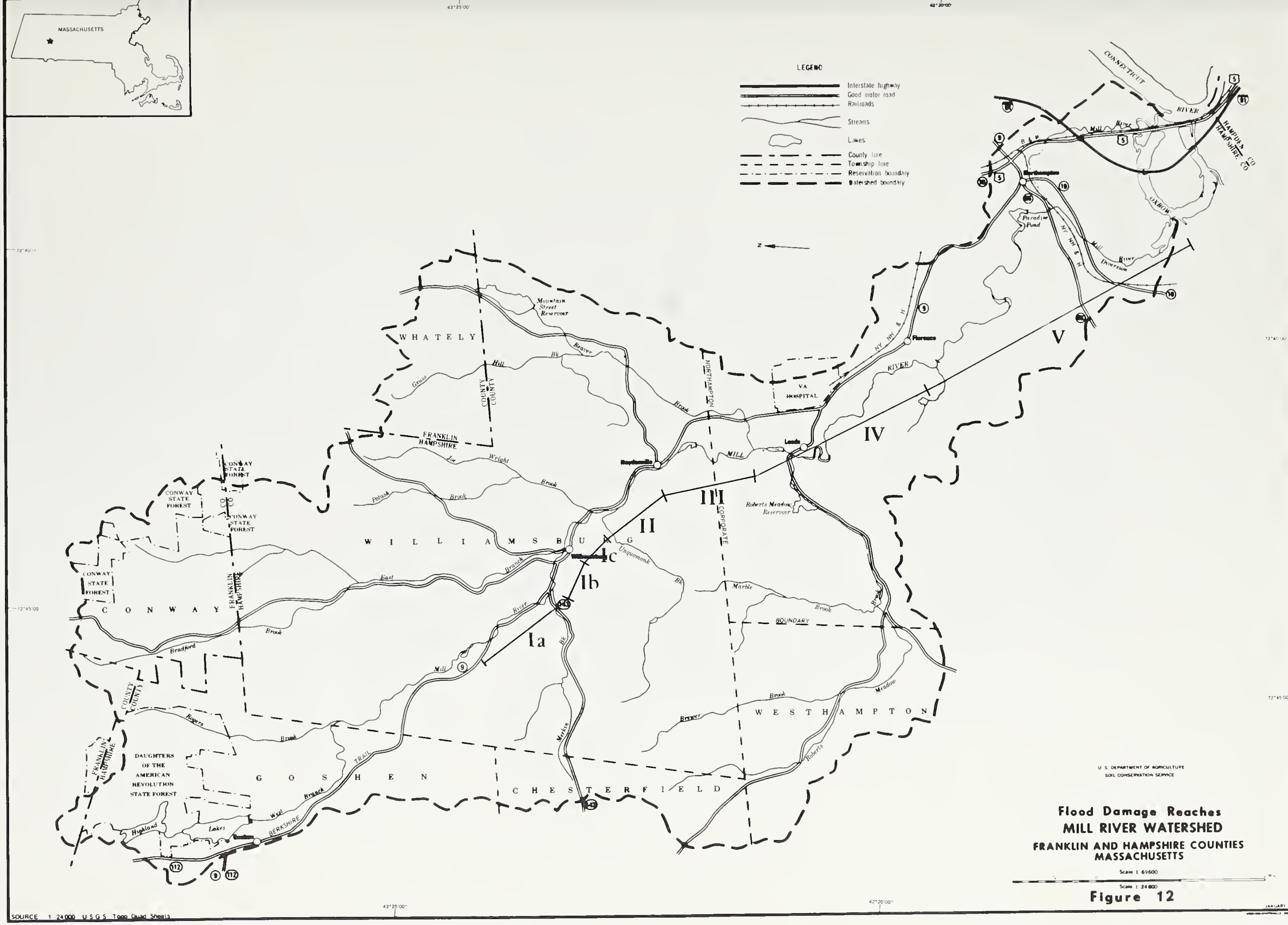
Sheet and gully erosion in the upland areas does not appear to be significant, and flood plain sediment and erosion damage appears to be minor. Some stream channel erosion occurs during periods of high flow, and channel sedimentation occurs to some degree behind existing lowhead dams on the Mill River.

Damages associated with a range of events have been summarized for the major reaches and are presented in table 17. Average annual damages are presented in table 18.

TABLE 17
SUMMARY
ESTIMATED DIRECT AND INDIRECT FLOOD DAMAGES
MILL RIVER WATERSHED
($1,000)1/

Reach of Stream	Chance of Occurrence 1% (100 yr)	2% (50 yr)	4% (25 yr)	10% (10 yr)	Single Flood Events 1955	1938
Ia	140	51	0	0	0	37
Ib	400	280	100	0	100	348
Ic	76	55	22	0	0	55
II	35	23	0	0	0	23
III	40	23	0	0	0	23
IV	230	167	92	0	15	167
V	66	40	8	0	0	45
Total Direct	987	639	222	0	115	748
Indirect (15%)	148	96	33	0	17	112
Total	1,135	735	255	0	132	860

1/ Price Base: 1973. Does not include future values.



U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Flood Damage Reaches
MILL RIVER WATERSHED
FRANKLIN AND HAMPSHIRE COUNTIES
MASSACHUSETTS

Scale 1:69600

Scale 1:24800

JANUARY 1974

Figure 12

TABLE 18
AVERAGE ANNUAL DAMAGES 1/
(Dollars)

Urban	$54,000
Road and Bridge	2,400
Agriculture	(minor)
Total Direct	56,400
Indirect	8,500
Total	64,900

1/ Price Base: 1973. Includes future values.

Existing Flood Management System

As a result of the 1936 and 1938 floods a local protection project for the city of Northampton was developed by the Corps of Engineers. This project closes off the valley of the Mill River just downstream from Paradise Pond at Smith College. About 1,900 feet of dike and 450 feet of floodwall contain the river and direct it through the 10,500-foot Mill River diversion to the Oxbow and the Connecticut River. This section also includes a drop structure and bridge, stoplog structures and street relocations.

About 5,000 feet of dike extend along the Connecticut River in the eastern part of the city. A pumping station which removes storm water from behind the dike is located where the dike crosses the old Mill River bed. There are stoplog structures where the dike line crosses U. S. Route 5 and the Boston and Maine Railroad. The project measures are shown in figure 13.

The project was completed in 1941 by the Corps of Engineers at a federal cost of $960,000 (about $7,000,000 at today's costs). Local costs were estimated at $150,000.

The project protects Northampton from flood flows on the Mill River and, in conjunction with upstream reservoirs in the Connecticut Basin, from flood flows on the Connecticut River. As of 1971, the Corps estimated that the works have prevented damages of $1,728,000. In a recurrence of the 1936 flood the project would prevent damages of $1,770,000. The downtown area of Northampton would be protected from a 100-year storm on the Mill River.

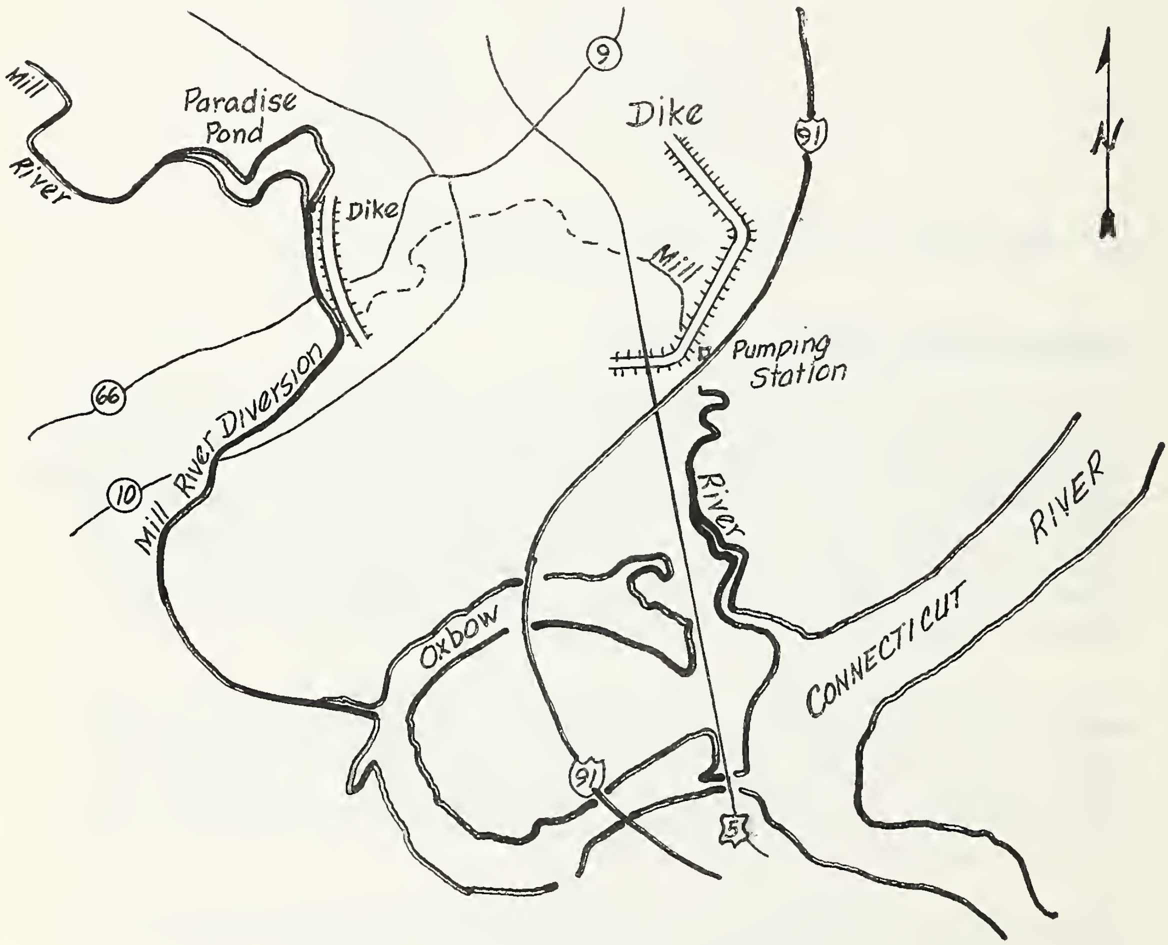


FIGURE 13
CITY OF NORTHAMPTON LOCAL PROTECTION PROJECT

Pro Brush Division of Vistron, Inc. installed a flood wall, gate valves and sump pumps as floodproofing measures in its plant. These measures have been effective in preventing damages.

Over the past 10 years conservation practices have been established in the Mill River watershed which help to conserve the soil and water resources of the area. The more common measures applied and the estimated extent of these measures appear in the following table.

TABLE 19
LAND TREATMENT MEASURES
MILL RIVER WATERSHED

Measure	Quantity
Tree Planting	16 acres
Open Channel	150 feet
Ponds	5 units
Woodland Improvement	21 acres
Woodland Improved Harvesting	265 acres
Drainage Main or Lateral	1,000 feet
Subsurface Drain	400 feet
Conservation Cropping System	216 acres
Pasture and Hay Land Planting	151 acres
Pasture and Hay Land Management	380 acres
Stripcropping	30 acres

These measures were applied to reduce erosion and sediment and to conserve the soil and water resources. Although peak flow control was not a goal of these measures, some gains may be realized.

About 10 years ago the city of Northampton organized a flood emergency board under the direction of the mayor's office. The board is composed of city department heads and the civil defense director and usually meets with the mayor twice each year to maintain readiness. The board has updated its flood emergency plan two or three times and facilitated the evacuation of residents of the Island Road and Riverbank Road area during a flood about six years ago. In February 1970 ice jams and flooding endangered several old mill dams on the Mill River in Haydenville and Leeds and the board was active in monitoring this situation and preparing for evacuation of residents in Leeds. Although one small dam failed, the ice jam broke and the danger passed.

Northampton is drafting a new zoning law. If approved, the law will control development in the flood hazard areas and create conservation zones along the river. Northampton will participate in the HUD flood insurance emergency program until a flood hazard boundary map is completed and actuarial rates are set. The Corps of Engineers is providing technical assistance in delineating flood hazard areas.

Williamsburg is also planning controlled use of flood hazard areas. Work is still in the preliminary stages, and no formal proposals have been made.

Except for the Corps of Engineers project, data is not readily available on the costs and benefits of the other measures.

Conclusions

The Mill River watershed area is susceptible to large amounts of rainfall in short periods of time as evidenced by the records of the 1938 and 1955 storms. During infrequent events, the Mill River can cause significant floodwater damages, primarily in Williamsburg and Florence. However, during the more frequent, less severe events, flooding is not widespread. The local protection project at Northampton, floodwalls at Florence and Look Park, and a relatively narrow and sometimes incised flood plain have all contributed to reduced flood damages.

Watershed residents have avoided flood-prone areas for the most part. However, conditions still exist which bear attention. The watershed is in a desirable growth area and there is developable land in the flood plain. However, the land is susceptible to flooding on an infrequent basis.

Actions taken in the towns indicate a desire to implement a flood management plan in the watershed including the protection of existing development in the flood plain and proposals to keep future development out of flood hazard areas.

LOCAL INTEREST GROUPS

After the three watersheds were selected for evaluation, a schedule was set for information meetings in each watershed to review the Soil Conservation Service plan of study with local citizens and to listen to such opinions and ideas as they might have concerning flood problems in the respective flood plains. In conjunction with the Conservation Districts and Regional Planning Agencies, meetings were held on the Passumpsic River at St. Johnsbury, Vermont, on September 12, 1973; on the Whetstone Brook watershed at Brattleboro, Vermont, on September 20, 1973; and for the Mill River watershed at Northampton, Massachusetts, on October 11, 1973. Notices of the meetings were sent to town selectmen, planning boards, conservation district supervisors, regional planning commission members and other local citizens involved in local resource planning activities.

The Citizens Advisory Group held public forums in the Connecticut River Basin to inform basin residents of the Supplemental Study and to listen to the ideas and opinions of local citizens. Pertinent points made by local citizens at five of the forums in the vicinity of the three watersheds relating to the Soil Conservation Service portion of the study have been summarized. Forums were held at Littleton, New Hampshire, on October 23, 1973; White River Junction, Vermont, on October 29, 1973; Brattleboro, Vermont, on October 30, 1973; South Deerfield, Massachusetts, on November 6, 1973, and West Springfield, Massachusetts, on November 13, 1973. Wide distribution of notices for these meetings was made through the press, radio announcements, and individual mailings.

Discussions dealing with flood damage reduction needs and possible alternative measures for reducing flood damages in each of the watersheds are summarized below.

Soil Conservation Service Meetings

Passumpsic River, Vermont. Eighteen people attended the Passumpsic River meeting in St. Johnsbury, representing the St. Johnsbury Board of Selectmen, Planning Commission, and Environmental Quality Commission; the Lyndon Planning Commission; the Burke Board of Selectmen; the Ryegate Board of Selectmen; the Waterford Planning Commission; the Citizens Advisory Group; the New England River Basins Commission; and the Soil Conservation Service.

There was much concern about the June 1973 flood and its effect on the Passumpsic River flood plain. Several alternative measures for flood damage reduction were discussed.

St. Johnsbury is presently zoned for the 100-year flood with some variances being considered. Some expressed the feeling that the flood plain offered the only desirable place for development in some areas. The town of Lyndon has flood plain zoning to the 20-year flood line. Development is allowed within the flood plain if the developer fills to a level which approximates the 20-year floodline elevation. Both St. Johnsbury and Lyndon have flood plain information study reports available for their use.

There was much discussion of flood plain management alternatives. Several members of the group felt that the best alternative was to dredge the Passumpsic River, and ideas ranged from the removal of small amounts of ledge and islands in the St. Johnsbury Center area to channelization of the entire river. Other suggestions included the use of Victory Bog as a floodwater retarding site to reduce flooding downstream on the Moose and Passumpsic Rivers and the preservation of Victory Bog as a controlled natural area.

Some landowners expressed the opinion that zoning and other such restrictive uses of the flood plain were very unfair to the property owner. They felt that if the landowner is taxed on the property he should have unrestricted use of the property and that a landowner should be reimbursed for any restrictions placed on his land.

During the June 1973 flood, the flood warning system worked effectively under the direction of the town manager and town and state police.

Whetstone Brook, Vermont. Fifteen people attended the meeting held in the regional planning office in Brattleboro. Represented were the Windham Regional Planning and Development Commission, the Marlboro Board of Selectmen, the Brattleboro Board of Selectmen and Planning Commission, the Vermont Water Resources Department, the New England River Basins Commission, and the Soil Conservation Service.

Public participation in the formulation of a project was discussed. It was suggested that it would be helpful to present citizens with a definite program before they could participate effectively. Getting information on the Supplemental Study to the general public was discussed as an important purpose for the public forums.

The town of Brattleboro is applying for planning assistance for Whetstone Brook Watershed through PL-566. Much of the data being collected for the Supplemental Study will be useful in formulating a PL-566 project. Several alternatives were discussed including dams, dikes, channelization, floodproofing, flood plain zoning, flood insurance, land treatment, open space, relocation and evacuation.

Mill River, Massachusetts. Twenty-three people attended the meeting held in Northampton, Massachusetts. Represented were the city of Northampton, the Northampton Conservation Commission, the town of Williamsburg, the Mill River Watershed Advisory Commission, the Connecticut River Watershed Council, the Lower Pioneer Valley Regional Planning Commission, the Massachusetts Department of Natural Resources, the New England River Basins Commission (Citizens Advisory Groups and consultants), private citizens (including faculty from University of Massachusetts and Smith College), and the Soil Conservation Service.

There was an apparent misunderstanding that the Mill River study was an environmental assessment and not one placing emphasis on flood management alternatives. It was explained that an environmental assessment was being made to help formulate structural and nonstructural flood management alternatives which would minimize adverse effects on the environment. Some were strongly opposed to the building of any flood control dams, dikes or channels.

There was interest in a program of flood plain delineation and flood insurance. Many of the group felt the supplemental study should get directly involved in the details of delineating flood plains. It was noted that this type of program is available through the Corps of Engineers and the Soil Conservation Service.

A comment was made that floodproofing should not be recommended as a flood management technique since it would encourage development in the flood plain.

Williamsburg is interested in flood plain delineation and the flood insurance program. The town is presently drafting regulations that would restrict building in the flood plain.

Some of the old dams in the Mill River are of concern. One person expressed the idea that it would be better to remove old dams rather than to build new ones. He felt that the old dams have caused flooding in the past.

The supplemental plan should recommend control or enforcement policy that would prevent erosion from becoming serious in developed areas.

Public Forums

Passumpsic River. Comments pertaining to the Passumpsic made at public forums in Littleton and White River Junction have been covered in the discussion of the Soil Conservation Service meeting.

Whetstone Brook. At the public forum held in Brattleboro additional points were discussed which related to Whetstone Brook. Questions on a possible PL-566 project dealt with the relative costs of installation of dams, landrights, and effects on landowners. Landowners have built effective dikes in some areas. Some felt that flood damage risk has been exaggerated and that there is no serious flooding problem.

The town of Brattleboro estimates that property values are about $9 million within the 100-year floodline as delineated in the Corps of Engineers flood plain information study.

Channelization of Whetstone Brook which would open the channel sufficiently to pass flood flows through the urban flood plain was discussed. Some felt this alternative provided a solution to the flooding problem while others felt that it would ruin the brook as a stream fishery.

Mill River. Comments pertaining to the Mill River made at the public forums in South Deerfield and West Springfield have been covered in the discussion of the Soil Conservation Service meeting.

General Points of Discussion. Five public forums were held near the watersheds which the Soil Conservation Service is studying. Points of general interest discussed at these meetings are summarized below:

Sedimentation in the streams is often listed as a major problem and its elimination should be considered.

Flood plains should be reserved for agricultural and recreational uses.

There should be a flood plain land acquisition program which would prevent intensive use of the flood plain.

Relocation of current residents should be considered, but because of high costs this may be unfeasible. Flood protection measures or floodproofing may therefore be necessary.

Financing of flood plain development should be regulated.

An educational program should be instituted to inform residents about the flooding problems of the area.

The pressure of school needs forces local towns to encourage development resulting in higher tax base.

Overland flooding is not necessarily beneficial to flood plains. Silts, sands and gravels deposited on farm land damage crops.

Protection against floods provides a false sense of security and encourages development in the flood plain. More emphasis should be placed on land use controls. However, development rights of landowners must be considered.

Upstream dams and wise land use should be used to control water. Upstream erosion and development contribute to downstream flooding.

PROCEDURES

The information reports on the Passumpsic, Whetstone and Mill present hydrologic and economic evaluations. The Citizens and Science Advisory Groups have expressed interest in the procedures used in obtaining this information. This section will report on the selection of floods to be tested, hydrologic evaluation, and the flood damage analysis procedures.

Flooding Characteristics of Tributary Streams in Connecticut River Basin

Selection of Floods

The major floods on the tributary streams of the Connecticut River nearly always resulted from intense rainfall during summer and fall months. North of the Sugar River in New Hampshire and Vermont, the floods of November 1927 and June-July 1973 produced the largest recorded tributary floods. South of this point, the September 1938 and August 1955 floods generated the major events, the 1938 flood was most severe north of the Connecticut State line and the 1955 flood caused the greatest damage south of the State line.

Basin characteristics of the tributary streams are such that, with few exceptions, intense rainfall events, independent of snowmelt, will be the determining factor in future flood plain use decisions. Selection of storms for use in evaluating the performance of alternative flood management systems was made with this in mind.

1. The watersheds were subjected to the major historical floods of record for their region.

2. The watersheds were studied in terms of storms having rainfall volumes with expected return periods ranging from once in 5 years to once in 100 years and in terms of rainfall distributions affected by watershed location and size.

The following table shows the storms used in evaluating the three watersheds selected:

TABLE 20

SELECTED STORMS USED
IN EVALUATION OF WATERSHEDS

Watershed	Drainage Area (sq.mi.)	Historical Storms (mo - yr)	Synthetic Storms & Distributions (Year - Dist[1/])
Passumpsic River	374	Nov. 1927 June 1973	5,10,25,100 - 1
Whetstone Brook	28	Sept. 1938 June 1973[2/]	5,10,25,100 - 2
Mill River	59	Sept. 1938 Aug. 1955	5,10,25,100 - 2

1/Rainfall Distributions 1 and 2 have respectively 21% and 38% of the entire rainfall occurring within a 30-minute period near the middle of the storm. As the size of the watershed under study becomes larger and its location lies further north, its rainfall distribution moves from 2 to 1. This is mostly because of increasing distance from moisture sources and the lack of uniformity in orographic and other meteorological influences as watershed size increases.

2/The June 1973 rainfalls, as recorded at Newfane, Vermont, and at Ball Mountain, Vermont, were both analyzed to show the effect on flood discharges of rainfall events approximately 10 miles apart.

Hydrologic Analysis

Analysis of the storms mentioned above was conducted as follows:

1. Delineation and measurement of drainage area on USGS topo map of subwatershed with similar hydrologic characteristics.

2. Inventory of soils and land use of each subwatershed.

3. Development of a measure of the subarea's ability to absorb and hold rainfall. This is designated as the runoff curve number (RCN). It is based on the soils and land use and varies from 0 to 100 (increasing with runoff potential).

4. Development of a measure of a watershed's response to a rainfall event. This is its time of concentration (T_c). It is computed by calculating the time for the various types of flow in which water will travel from the most hydraulically remote portion of the watershed to the outlet.

5. Extraction of rainfall volumes from Weather Bureau Technical Paper-40 for 24-hour storms of the various frequencies being evaluated--usually 5, 10, 25, and 100 years. Historical events are evaluated using rain gage data which best represent the study area.

6. Determination of a rainfall distribution, i.e., how the rainfall proportions itself during its 24-hour occurrence. These distributions are based upon regionalizing the country by rain types. A rainfall distribution is created by placing the largest recorded 30-minute rainfall approximately in the center of a 24-hour period. The next largest 30-minute rainfall is placed immediately behind the first and the third largest immediately in front of the first, etc. See footnote 1 for above table. Distributions for historical events are determined by use of the appropriate recording gage.

7. Development of a runoff volume via runoff equation based upon the RCN and rainfall:

$$Q = \frac{(P - .2S)^2}{P + 0.8S}$$

P = rainfall volume (inches)

$$S = \frac{1000}{RCN} - 10$$

This rainfall volume is developed for each time increment of the rainfall event (usually 30-minute Δt).

8. Development of incremental hydrographs using the runoff volume for each storm burst. The peak of each is based upon:

$$qp = \frac{484\ A\ \Delta Q}{\frac{\Delta D}{2} + .6T_c}$$

A = area (sq. miles)
ΔQ = incremental runoff (inches)
ΔD = duration of stormburst (½ hour)
T_c = time of concentration (hours)

The time of peak is assumed to be $\frac{\Delta D}{2} + .6T_c$ and the time from initial runoff to final is 2.67 times the time of peak.

9. Addition of each of the above hydrographs as they occur in the storm event to produce a composite hydrograph for each sub-watershed.

10. Routing of each hydrograph through the watershed to the evaluation point using the Convex method. This method is based upon the natural storage potential of the valley and channel.

$$\text{Outflow}_2 = (1-C)\ O_1 + CI_1$$

C = measure of natural storage
O_1 = outflow to reach at time 1 (cfs)
I_1 = inflow to reach at same time (cfs)
O_2 = outflow at end of next time increment (cfs)

11. Accumulation of hydrographs for each subarea as the streams join.

12. Computation of discharge-frequency relationships for various evaluation points in the watershed using the same procedure for each frequency storm mentioned above.

This procedure is described generally on page C-60, Volume II of the Connecticut River Basin Comprehensive Plan.

Procedures for Economic Analysis
Small Watershed Investigation

Economic analysis is conducted to determine the dollar value of an object, situation, or event. In the Connecticut River Basin Study, an economic analysis was used: (1) to show the damages done by past floods, (2) to show the amount of damages that would occur if the same floods happened today, and (3) to show what the damages would be if the same events were to take place in the future. The analysis was also used to demonstrate how damage values fluctuate if various preventive measures are taken.

The following steps were generally followed:

1. Basic information concerning the watershed, including maps, pertinent studies by others, news stories or other published records and similar material was assembled.

2. The stream and adjoining flood plain were divided into reaches to facilitate the study process. Each reach had uniform characteristics throughout, being wholly an urban area or a flat or steep section of stream, etc.

3. A field investigation was conducted to study each reach. The numbers of homes, businesses, acres and types of land, and other features subject to flooding were noted. Through talks with property owners and public officials and the use of records, the damages caused by past floods were estimated. Usually the investigation centered around some past major flood event such as 1927 or 1938. Later storms such as the June 1973 event were considered in the supplemental study.

4. Stage-damage curves were developed based on the major floods (1927, 1938, etc.). These showed the amount of damages expected if flood water should reach greater or lesser depths than it did during the major flood.

5. Frequency-damage curves were developed. These estimated how frequently major floods as well as lesser ones could be expected to occur over a period of years and the value of damages they would cause. Frequencies of 100-year, 50-year, 25-year, and 10-year were generally used.

   These same curves were used to estimate average annual damages over a period of 100 years.

6. Damage values in this study include both direct and indirect damages. Damages are based on present valuation of existing properties in the flood plain.

   Direct damages are those caused by contact with the flood water such as damage to buildings and loss of furniture. Indirect damages (usually 15% of direct damages) are losses experienced because of the flooding but not from direct contact with it, such as extra miles driven and time spent following a detour around a washed out bridge.

   Future valuation of existing property was based on projected trends in prices and personal income. OBERS projections were used.

FLOOD MANAGEMENT ALTERNATIVES

A wide range of conditions exist in the three watersheds being studied. Stream profiles range from very steep to flat; flood plain widths very considerably; some reaches of stream are intensively developed while others remain open, and local opinion appears to vary concerning what must be done to deal with the flooding. As a result, a wide range of flood management alternatives must be studied. A list and short descriptions of the types of alternatives which might be considered follow.

Dams. The purpose of dams is to store water during times of excess flow and to release it after the threat of flooding is past. Dams can lower flood stages along stream reaches and provide other benefits to surrounding areas. Drawbacks include land requirements and stream and stream flow alterations.

Channel Work. Channel work is done to increase the carrying capacity of a channel to reduce flood stages. This is done by widening, deepening, clearing, or straightening an existing channel. Channels usually increase peak flows in downstream reaches, and may alter fish population and the appearance and natural setting of a stream.

Dikes, Levees and Floodwalls. These measures are installed to confine flood flows to a restricted channel and prevent flooding to outlying areas. They provide direct and specific flood prevention, often in areas where other means are not feasible. Dikes, levees and floodwalls intrude on the flood plain and can increase flood stages at the site and upstream. The loss of natural flood storage may also affect downstream areas. Catastrophic losses can result if these measures are overtopped.

Floodproofing. Floodproofing measures include structural changes or property modifications to reduce or eliminate flood damage. The measures apply to existing or newly constructed properties in the flood plain allowing individuals to solve flooding problems where collective action is not possible or desired.

Flood Plain Zoning. This is a regulating measure used to control the use and development of land and properties in flood hazard areas. The purpose is to keep people and development out of the flood plain. Its effectiveness depends on the enactment of local controls by municipalities. It does not protect against loss of life and property for those who presently reside in the flood plain unless provisions are made for the removal of nonconforming uses and control of changes to existing structures.

Flood Insurance. The National Flood Insurance Program, administered by HUD, provides subsidized flood insurance to potential flood victims in eligible communities. In return for the provision of subsidized insurance, local governments must adopt and enforce land use and control measures that will guide development in flood-prone areas to avoid or reduce future flood damage. This type of control is usually provided by a building permit system or subdivision regulations.

Recent changes have been made in the program. Flood insurance at subsidized rates is available in amounts up to $35,000 for single family residential structures and up to $100,000 for other structures. Additional insurance is available for contents coverage. The new law also requires states or local communities to participate in the flood insurance program as a condition of future federal assistance in developing flood hazard areas.

The key to the effectiveness of such a program is the establishment of sound actuarial rates and the enforcement of appropriate land use controls.

Subdivision Regulations. Subdivision of land involves the division of land into parcels for building or sale. Subdivision regulations can specify certain requirements which will reduce flood losses. This can be done by prohibiting subdivision of land in flood hazard areas, prohibiting encroachment into floodway areas, requiring that any construction be free from flood damage, and specifying construction techniques which will prevent increased flood flows.

State and local subdivision regulations have wide potential in protecting the buyer of flood-prone lands and reducing potential flood damages. They are most useful when used in conjunction with zoning and building codes. They apply only to new development.

Building Codes. Building codes regulate the construction material and structural design used in buildings. These regulations have often applied to control fire and safety hazards and to improve sanitary conditions but have not established sufficient requirements to lessen flood damages. A 1972 publication, "Floodproofing Regulations", by the Corps of Engineers, has provided needed guidance to local interests.

Other Land Use Controls. Public acquisition, easements, tax adjustments, open space policy, government development policy and land use planning are the other methods of controlling development of flood plain lands.

Warning and Evacuation. People and property can be temporarily evacuated from the flood hazard areas when adequate warning is given. This procedure can help reduce economic losses and loss of life, but its effectiveness relies on adequate warning, effective communication and the cooperation of those involved.

Relocation. Relocation involves permanent evacuation of people and property from the flood plain. It is effective in eliminating flood damages. It can be used most effectively with other redevelopment policies, in mobile home park areas, and in areas ravaged by past floods. Limitations of this practice are high cost and the disruption of established areas.

Land Treatment. Land treatment practices can increase the water absorption and holding capacity of land and reduce erosion. Although the effect of these measures on peak flows is minimal in the Connecticut Basin, these measures will be helpful in offsetting the erosion and sediment effects of residential, commercial, and industrial development.

ALTERNATIVE FLOOD MANAGEMENT SYSTEMS

Flood management measures will be used to formulate alternative flood management systems. This task was identified as part of the Phase 1 studies but has not been completed at this time. Phase 2 studies will formulate, evaluate, and compare a minimum of three types of alternative plans.

1. National Economic Development

2. Environmental Quality

3. No Action.

The national economic development plan (primarily structural) and the environmental quality plan (basically nonstructural) will be the limits within which other alternatives are studied. The no action plan is defined as the measures that would probably be implemented if no plan were proposed by this study.

EVALUATION CRITERIA

The Soil Conservation Service will develop data to assess flood damages in upstream watersheds. During Phase 1 this applied to the existing flood management systems. During Phase 2 alternative flood management systems will be evaluated.

To assure consistency in study analysis the Soil Conservation Service will use uniform evaluation criteria for each watershed. These criteria are provided in Principles and Standards for Water and Related Land Resources published by the Water Resources Council.

The Soil Conservation Service will develop only part of the data required to compare alternatives. Other agencies and disciplines have responsibilities for developing additional data for the environmental, social and economic factors. The results of the various tasks will be combined so that all factors may be considered in plan selection. The Soil Conservation Service will present its findings in a manner consistent with the public information display accounts as outlined in the Principles and Standards and will then be compatible with the findings of other agencies guided by the same criteria.

APPENDIX 1

DISCHARGE-STAGE-DAMAGE-FREQUENCY RELATIONSHIPS

The hydrologic and economic evaluations for selected reaches in the Passumpsic, Whetstone and Mill River watersheds are presented on coaxial graphs to clarify the approach used in computing flood damages. They will also be useful in later studies which will identify modifications in the hydrologic and economic relationships.

The basic relationships, stage-discharge, discharge-frequency, stage-damage, and damage-frequency have been used for many years by the Soil Conservation Service[1] in evaluating flood management plans. A description of the method and its potential usefulness is presented in a paper distributed to program participants by New England River Basins Commission.[2]

The reaches for which information is presented are selected on the bases of flood damage magnitude and public interest. In the Passumpsic two reaches were selected, one in Lyndonville and one in St. Johnsbury Center. In the Whetstone, Reach III was selected because of the large number of mobile homes it contains and Reach V because it contains Melrose Terrace. Both of these reaches represent potentially dangerous situations. In the Mill River watershed, Reaches Ib and IV were selected because they represent most of the flood damage potential in the watershed.

The use of curves is described in the above-mentioned paper and other references and will only be summarized here. For defining the existing condition of the watersheds in this study the desired indicators were direct damage for various frequency events and average annual damages. In future studies, the relationships will be altered as structural and nonstructural measures are tested.

Using hydrologic procedures described in this report, the hydrologist arrived at discharge-frequency relationships. By routing flood flows through the watershed, stages associated with various flows are determined for a particular location. For each stage

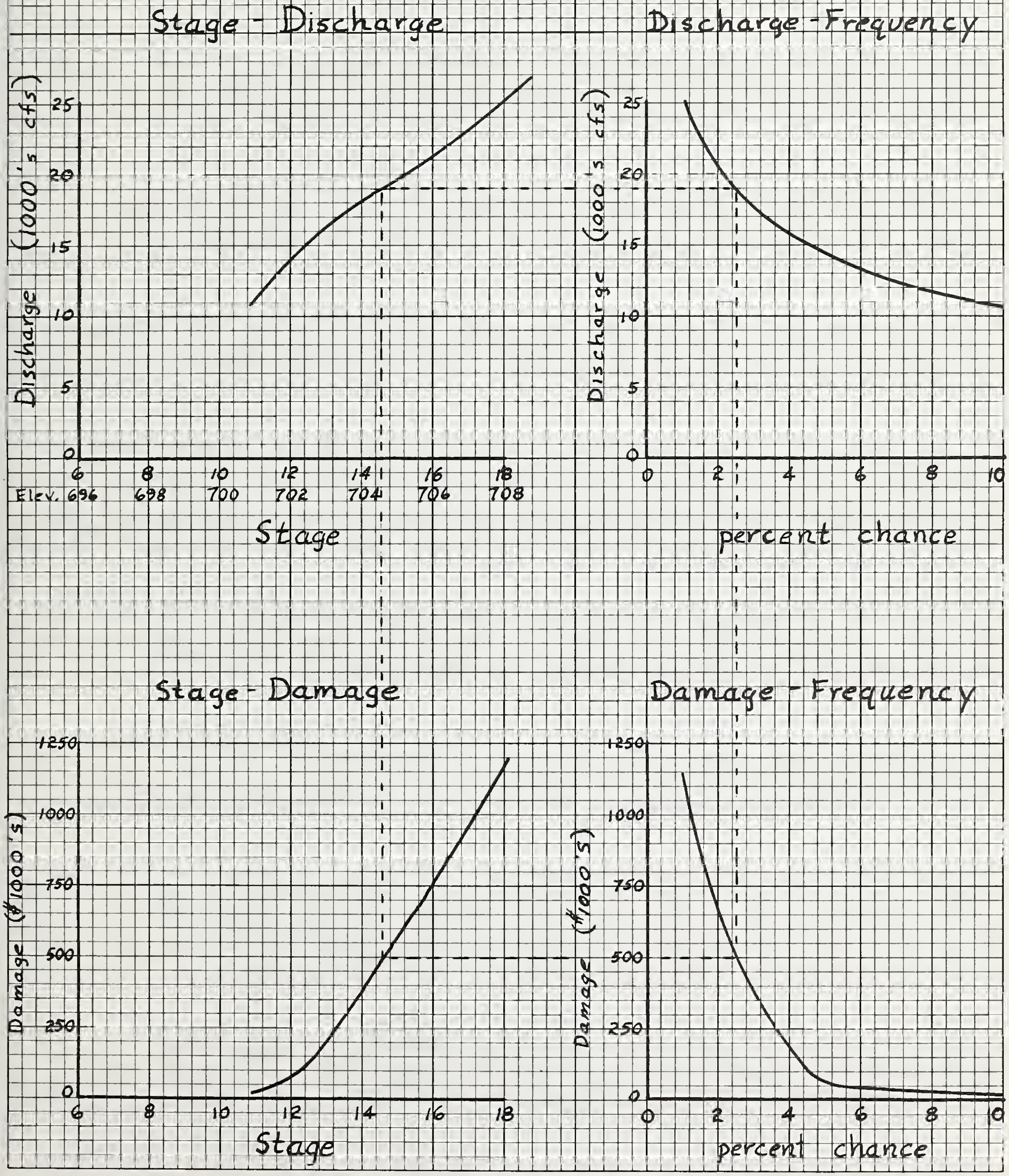
1/ SCS Economics Guide.

2/ "An Approach to Evaluation of Structural and Nonstructural Flood Management Methods." A staff technical paper prepared by S. Lawrence Dingman, August 6, 1973.

there is an associated damage. When this stage is related to the frequency, a resulting damage-frequency relationship can be obtained. When damages are determined for a range of frequencies a damage-frequency curve can be drawn.

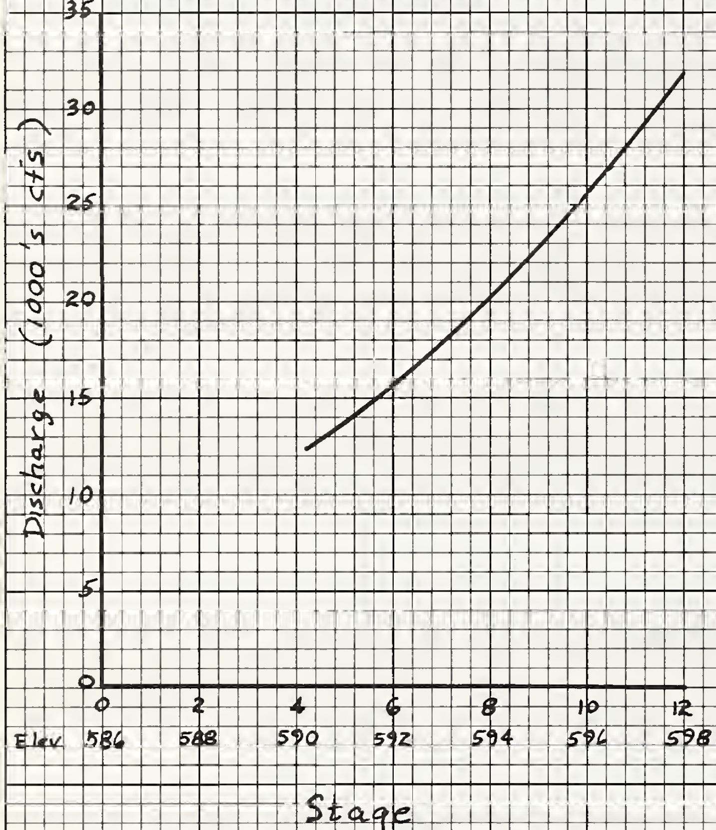
The curves are beneficial in that they present complex data (which are inter-related) in a simple form.

Flood Damage Reach V
Passumpsic River

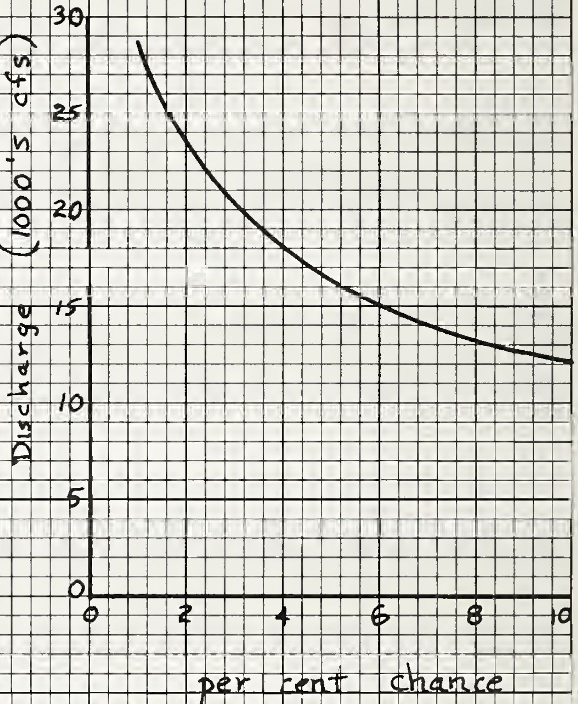


Flood Damage Reach VII
Passumpsic River

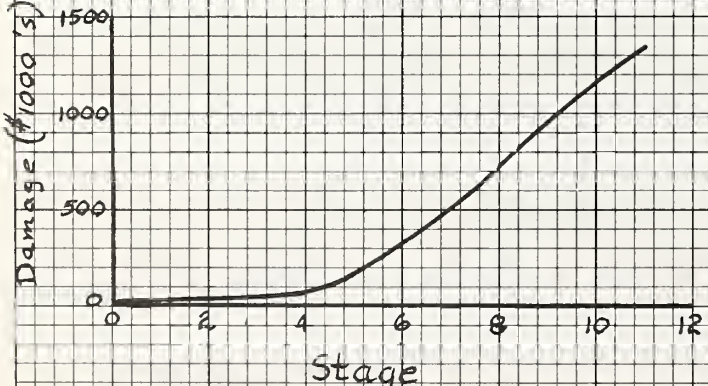
Stage - Discharge



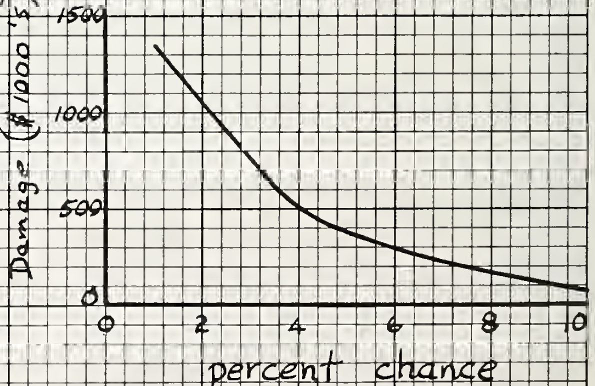
Discharge - Frequency



Stage - Damage

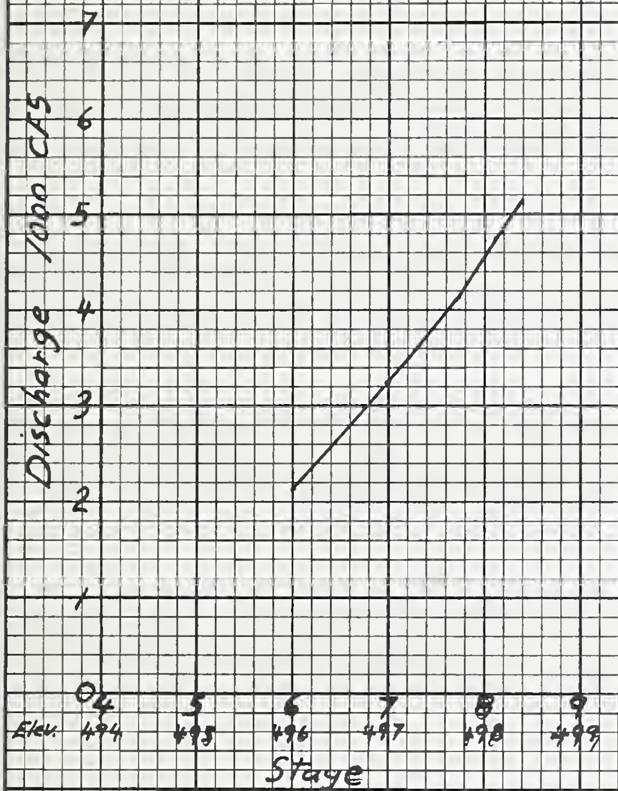


Damage - Frequency

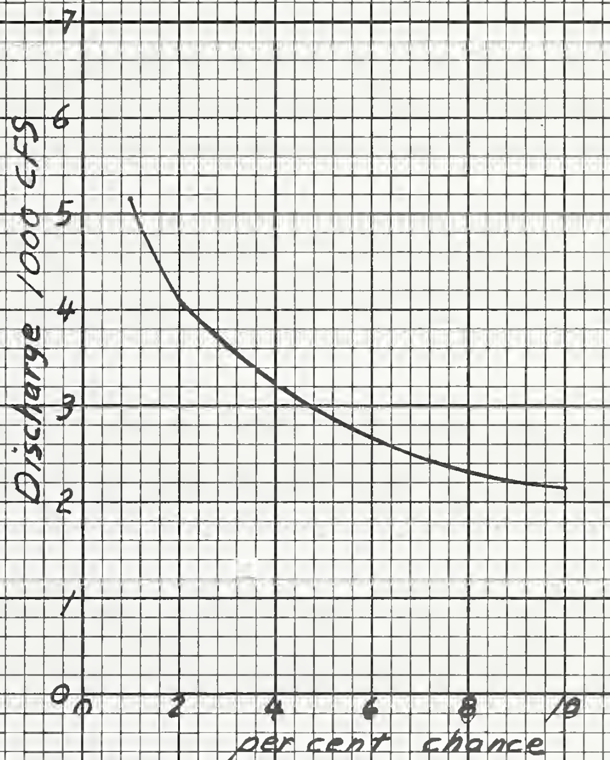


Flood Damage Reach III
Whetstone Brook Watershed

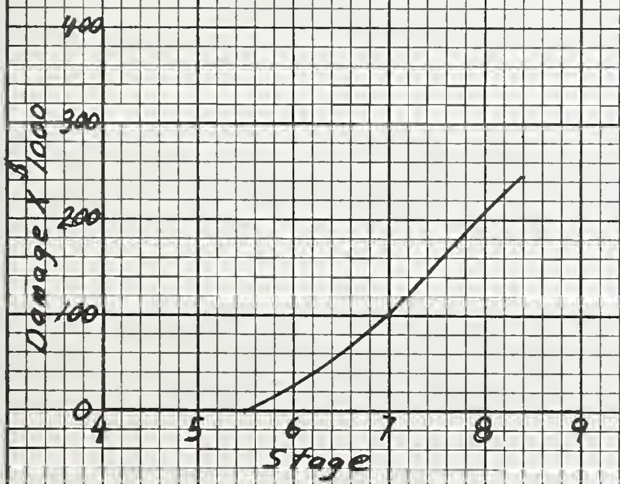
Stage-Discharge



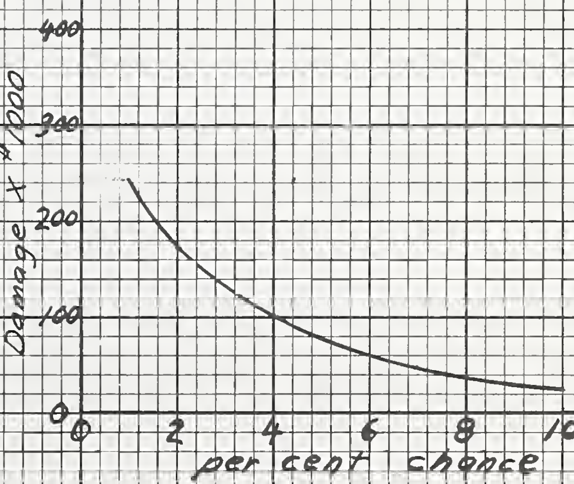
Discharge - Frequency



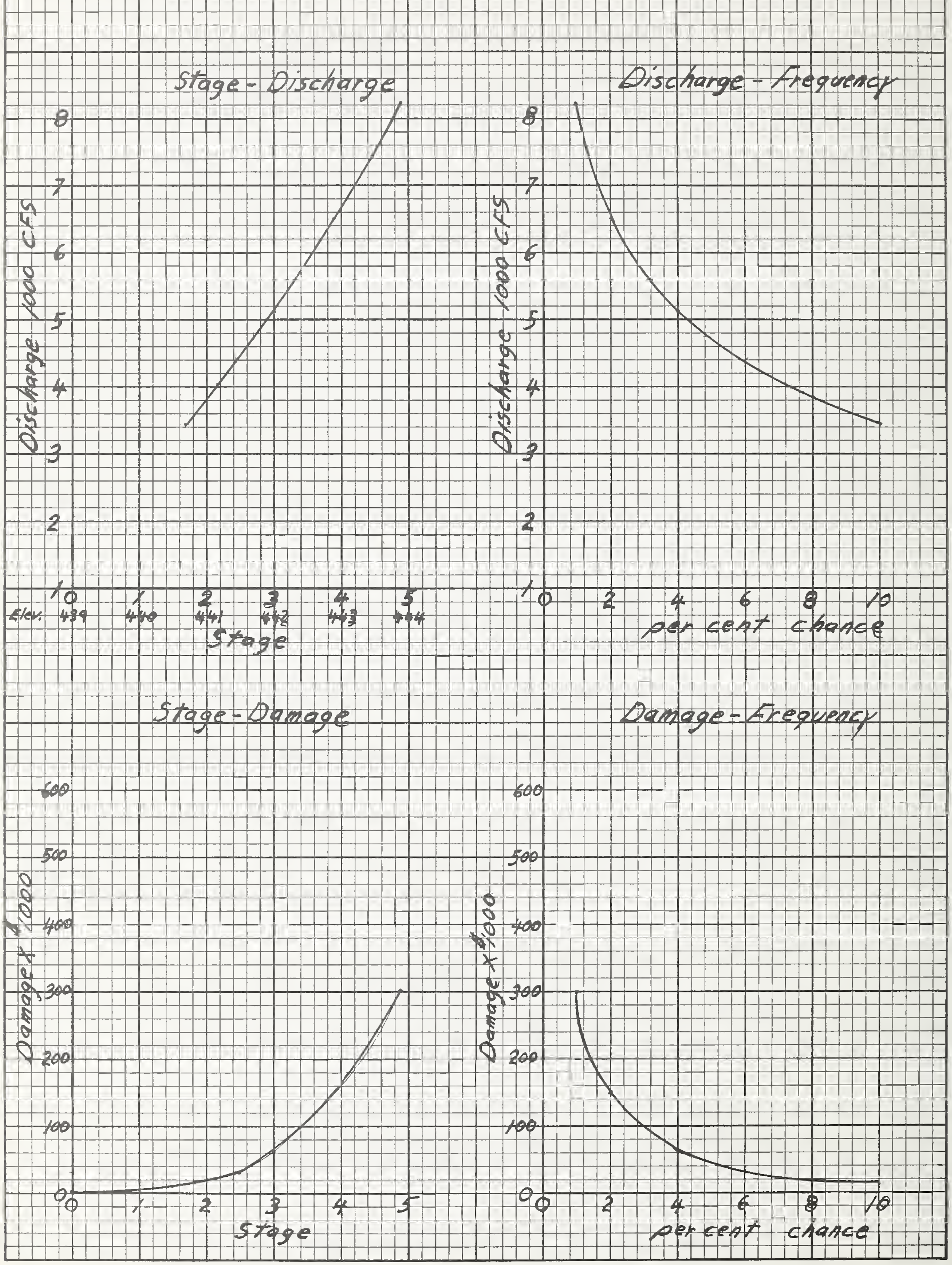
Stage - Damage



Damage - Frequency

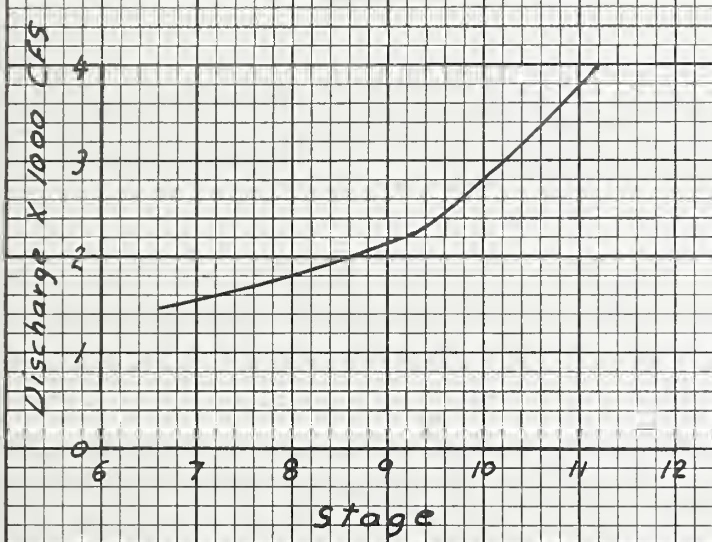


Flood Damage Reach V
Whetstone Brook Watershed



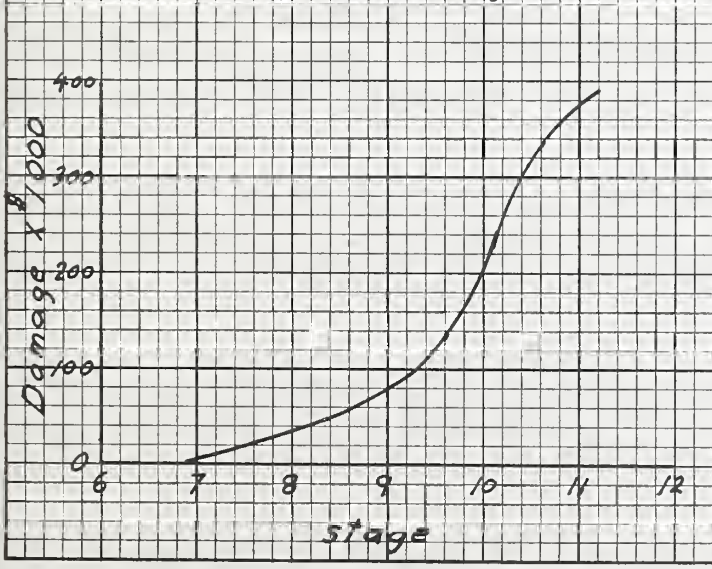
Mill River
Flood Damage Reach IB

Stage - Discharge

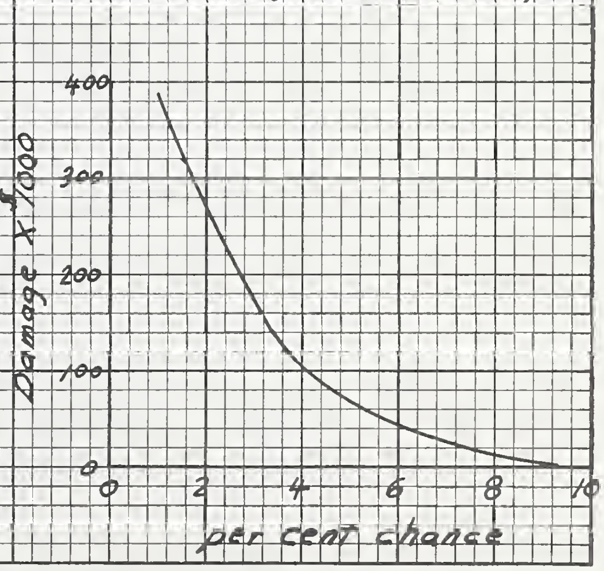


Discharge - Frequency

Stage - Damage

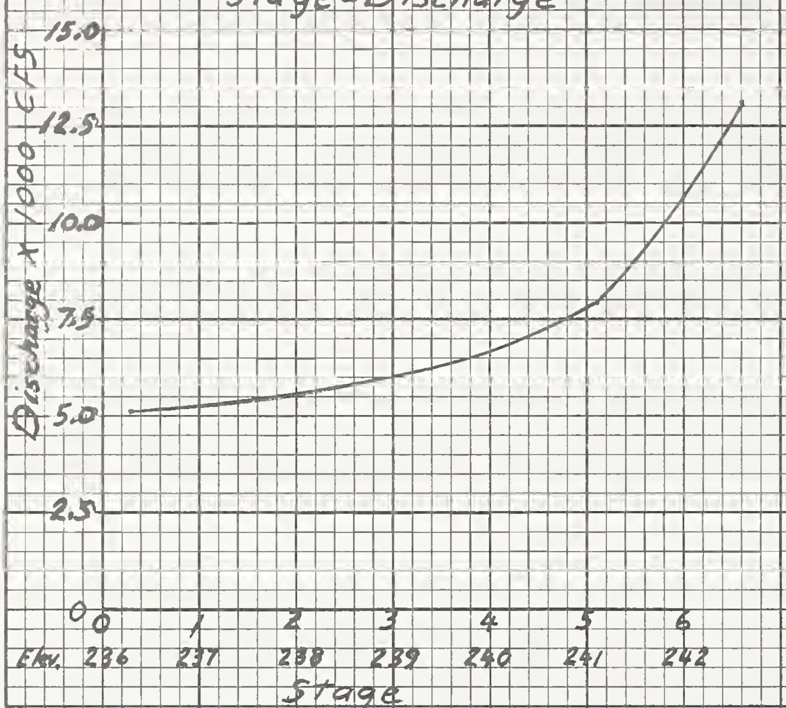


Damage - Frequency

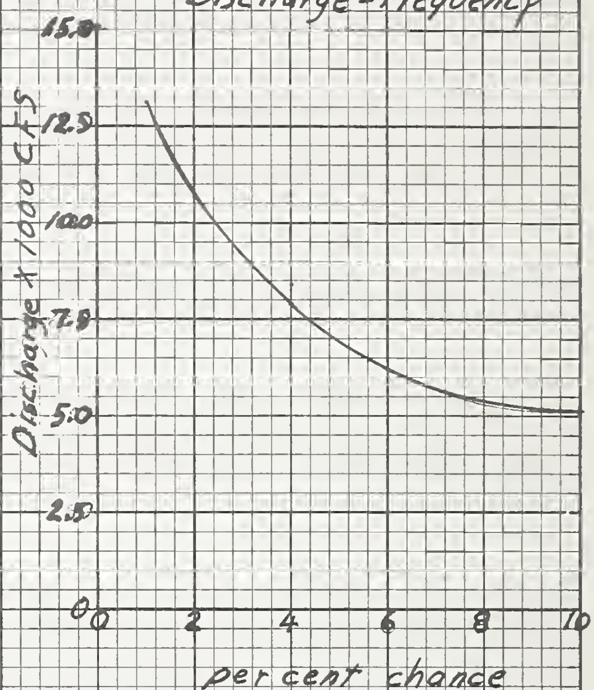


Mill River
Flood Damage Reach IV

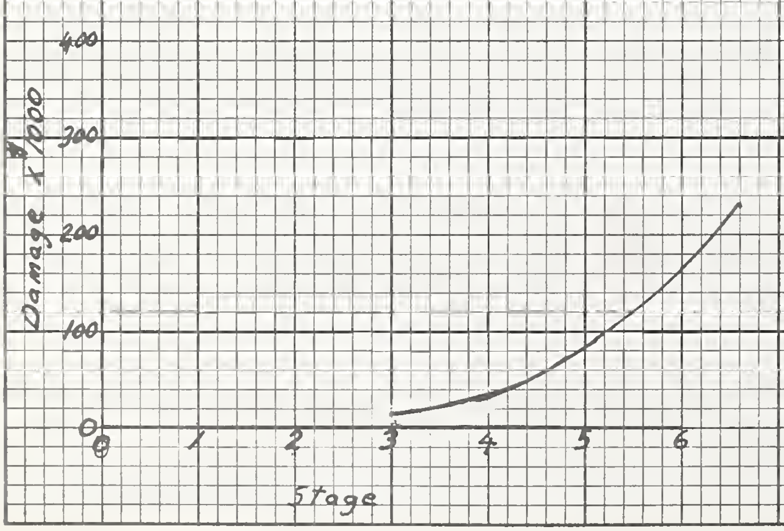
Stage-Discharge



Discharge-Frequency



Stage-Damage



Damage-Frequency